

THE 1896 ANNANDALE SEWER AQUEDUCTS



over Johnstone's Creek



and over White's Creek

SUBMISSION FOR AN HISTORIC ENGINEERING MARKER

from

The Engineering Heritage Committee
Sydney Division, Institution of Engineers, Australia
1993

Commemorative Plaque Nomination Form

To:
Commemorative Plaque Sub-Committee
The Institution of Engineers, Australia
11 National Circuit
BARTON ACT 2600

Date:..... May 1993

From..... Engineering Heritage Committee

.....

.....

Sydney Division

(Nominating Division or Branch)

The following work is nominated for an *Historic Engineering Marker/National Engineering Landmark award:

Name of work Sewer aqueducts, Annandale

Location, including address and map grid reference if a fixed work see attached map

.....

.....

Owner Water Board

In support of the nomination the following information is provided:

For an Historic Engineering Marker (HEM) see attached

(1) Proposed wording on HEM#

(2) Justification - please make data as complete as possible.# see supporting papers

For a National Engineering Landmark (NEL)

(1) Date of construction (or other significant dates).

(2) Names of key professional personnel associated with the work.#

~~(3) Historic engineering significance of the work.#~~

(4) Comparable or similar works (a) in Australia (b) overseas.# (a) None (b) not known

(5) Features or characteristics setting the work above other engineering works.# see attached papers

(6) Contribution towards the development of engineering and/or the nation.# see plaque wording and attached papers

For all Nominations

The following documentation is attached in support of the nomination: photographs and
(List all documents, photographs, etc, and enclose black and photographs). historical documents

The nomination has been discussed with the owner of the work who has indicated

Acceptance of nomination - see attached letter


(Include statement regarding owner's attitude)

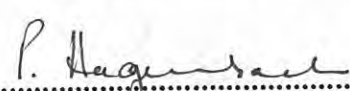
A copy of this submission has been sent to the Secretary of the

Division at

(For completion by a nominating body other than a Division)

In the event of this nomination being approved the nominating body will organise an suitable presentation/
unveiling ceremony.


Chairman of Nominating Committee


(Secretary of Nominating Committee)

* Delete as appropriate

Where there is insufficient space, attach additional papers



WATER BOARD

SYDNEY – ILLAWARRA – BLUE MOUNTAINS

Office of the Chairman

Our Ref: C/I 93/17

Mr Paul Hagenbach
Hon. Secretary
The Institution of Engineers, Australia
Sydney Division
Engineering Heritage Committee
PO Box 138
MILSONS POINT NSW 2061

25 MAR 1993

Dear Mr Hagenbach

On behalf of the Chairman, I am pleased to accept your offer for the Dedication of Plaques in recognition of the engineering heritage significance of the Board's aqueducts at Whites Creek and Johnstons Creek, Annandale. The Board will be delighted to co-host an appropriate ceremony later this year.

Both aqueducts have been listed on the Board's Heritage and Conservation Register as important items of the Board's cultural heritage. They have also been classified by the National Trust of Australia (NSW) as examples of the earliest major reinforced concrete structures to be built in NSW.

The heritage tours of Centennial Park Reservoir No. 1 last year demonstrated the extent of public interest in Australia's engineering heritage. Your Committee's actions in selecting outstanding examples for the dedication of plaques is a positive initiative which continues this education process.

If you wish to obtain further details on these two aqueducts please ring Mr Reece McDougall, A/Senior Environmental Scientist, on 269 6892. The Chairman has asked Mr McDougall to contact the Institution to make the appropriate arrangements for a ceremony and he looks forward to future heritage projects that provide opportunity for close liaison between our organisations.

Yours sincerely,

GEOFF HENSTOCK
Executive Officer
to the Board.

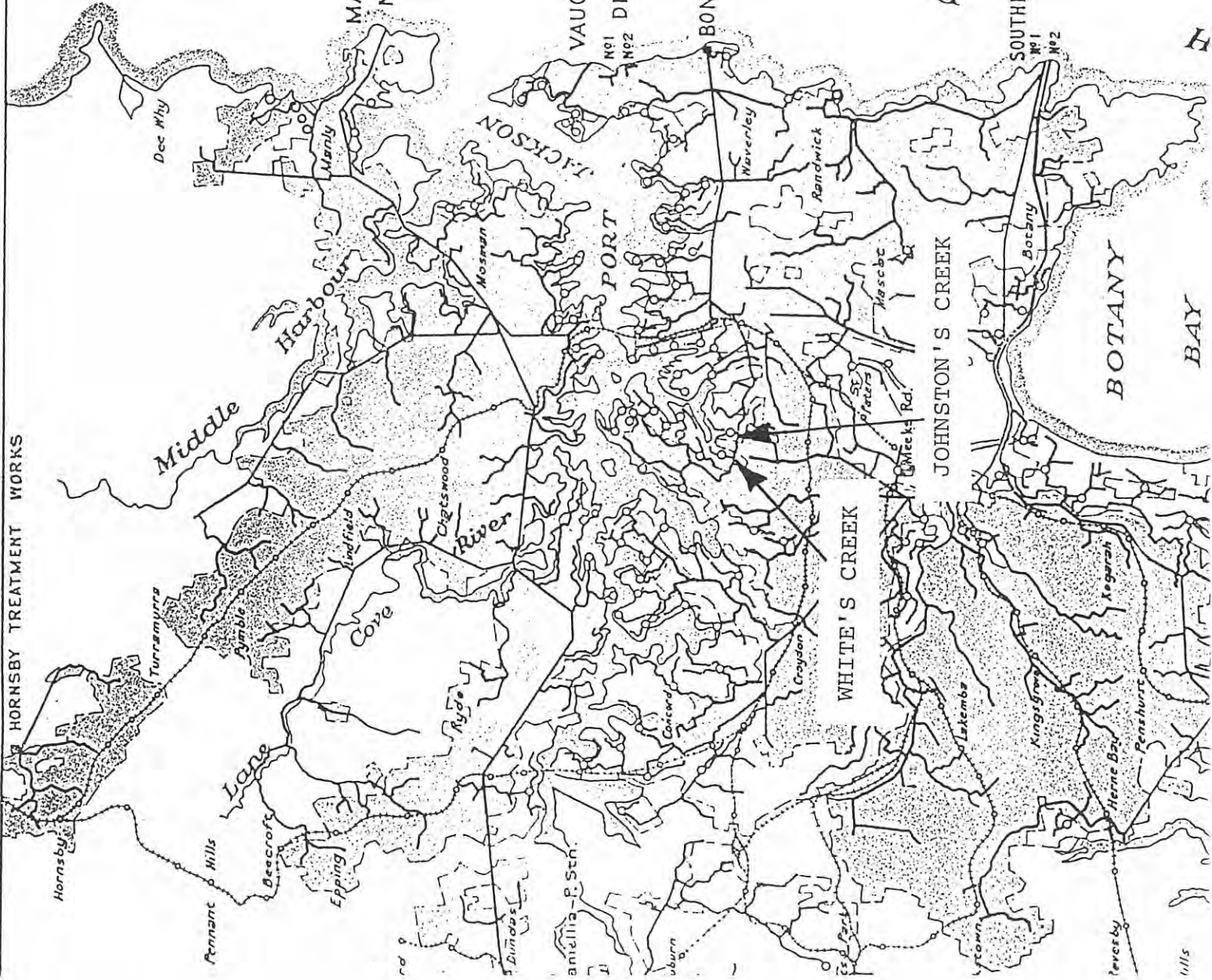
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crest

HISTORIC ENGINEERING MARKER

ANNANDALE SEWER AQUEDUCTS

THESE 1896 AQUEDUCTS WERE THE FIRST STRUCTURES IN AUSTRALIA TO INCORPORATE MONIER ARCHES AND WERE DESIGNED BY W. BALTZER TO CARRY THE NORTHERN SEWER MAIN ACROSS JOHNSTONE'S AND WHITE'S CREEKS. AFTER THE CHOICE OF THIS NEW FORM OF CONSTRUCTION HAD BEEN INVESTIGATED BY A ROYAL COMMISSION, THE CONTRACTOR - CARTER, GUMMOW AND FOREST HAD TO LODGE A LARGE SUREITY AND GUARANTEE MAINTENANCE FOR THREE YEARS. THE SUCCESS OF THE WORK PIONEERED THE INTRODUCTION OF REINFORCED CONCRETE TO AUSTRALIA.

DEDICATED BY
THE INSTITUTION OF ENGINEERS, AUSTRALIA
AND THE WATER BOARD. 1993



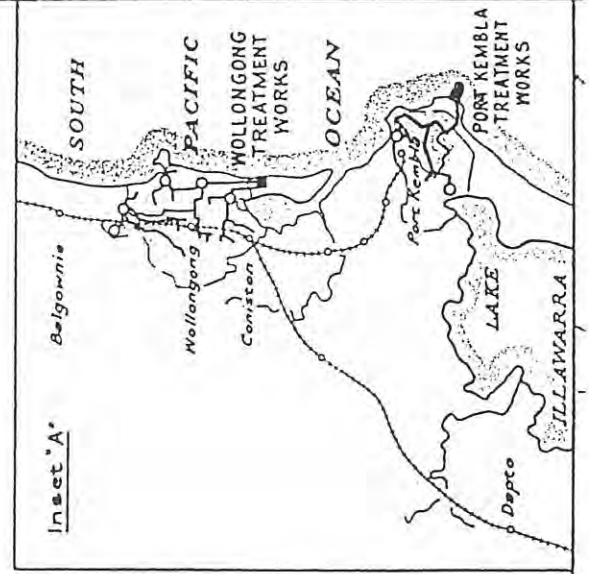
OCEAN

SEWERAGE SYSTEMS 1960



—LEGEND—

- MAIN SEWERS SHOWN THUS ———
- PUMPING STATIONS SHOWN THUS —○
- RISEING MAINS SHOWN THUS - - - - -
- AREAS DRAINING DIRECT TO OUTFALLS SHOWN THUS [Patterned Box]
- AREAS DRAINING TO PUMPING STATIONS SHOWN THUS [Empty Box]



PACIFIC

SOUTHERN & WESTERN SUBURBS
OCEAN OUTFALLS

BOTANY BAY

PORT KEMBLA
TREATMENT
WORKS

LAKE

DEPTO

WILLAWARRA

ANNANDALE/GLEBE	JOHNSTON'S CREEK SEWER AQUEDUCT	In Hogan Park of Taylor Street
Town or District)		
Post Code 2037	Fun of	
Local Govt Area	Leichhardt	
Author of J M Collocott		
Proposal		
Date of July 1987		
Proposed CLASSIFIED	(Name or Identification of Listing)	(Address or Location)
Listing Category	Bibliography 1. "The Water Supply, Sewerage and Drainage of Sydney" - by W V Aird, Halstead Press 1961; 2. Early Reinforced Concrete in NSW", D J Fraser, PhD, MIE Aust; Transactions of the Institution of Engineers Australia, Multi-Disciplinary Engineering - Vol GE9 No 2 Oct 1985	Owner and Address Metropolitan Water Sewerage & Drainage Board, cnr Pitt & Bathurst Sts SYDNEY 2000
Committee Trust Use)		
Council APPROVED CL		
Trust Use) 2-11-87		

Briefly cover the points on the following check list where they are relevant and within your knowledge.

Description

1. Introduction and Historical Background

Style

Construction 1.1 In 1859, Sydney had a rudimentary sewerage system of five sewers draining to the Harbour and serving an area little larger than what is now the central business area of the city proper (See Fig 1).

Use

Architect/s

Builder/s

Date of Construction

Present

Condition

History

Owners

Boundaries of proposed listing

By 1889, this had grown to some ten kilometres of main sewers and 103 kilometres of subsidiary sewers serving 18,000 properties in the Sydney City area, and about 25 kilometers serving 6,750 properties in the suburbs of Darlington, Paddington and Redfern.

The system was controlled by the City Council and continued to discharge to the Harbour until 1889 at which time two major projects initiated by the Government (and constructed by the Public Works Department between 1880 and 1889) were commissioned. These were:

(i) An ocean outfall sewer discharging to the ocean near Bondi.

(ii) A southern system of sewers draining to a sewage farm at Botany.

(See over)

Reasons for listing

1. Together with the White's Creek Aqueduct, Johnston's Creek aqueduct is a key component of the extension to the Bondi Ocean Outfall Sewer. The B.O.O.S. was completed in 1889 to become the basis of the first of the three major ocean outfall sewers which serve Sydney to this day, and the aqueduct was completed in 1897 only 8 years later.

2. The status of the aqueduct (along with the similar White's Creek aqueduct) as being one of the first two major reinforced concrete structures to be built in NSW, and amongst the first to be built in Australia.

3. The aqueduct is a good example of a sewer structure which can be easily interpreted. The great majority of any major sewerage system is hidden underground but there are places where crossing gullies, rivers or river flats at which the sewage carrying structures can be viewed. The Johnston's Creek aqueduct is such a case.

Sketch plan and photos

Attach additional photos if any.

JOHNSTON'S CREEK SEWER AQUEDUCT (CONTINUED)

In 1888, the new Board of Water Supply and Sewerage was created, and, in 1889, it took over the old City Council system and the Government's new works. (See Fig 2). The new works are the basis of the two major sewerage systems which to this day still serve the greater Sydney area south of the Harbour, i.e.:-

- . The B.O.O.S. - Bondi Ocean Outfall Sewer
- . The S.W.S.O.O.S. - Southern Ocean Suburbs Ocean Outfall Sewer.

- 1.2 The Johnston's Creek sewer aqueduct is an original key component of the upstream extension of the B.O.O.S. which was known as the Northern Main Sewer, and carries the sewage derived from the Glebe/Balmmain/Annandale areas across Johnston's Creek on its journey to the ocean at Bondi. The externally rectangular conduit has an internal U shape 3' 6" wide by 4' 6" deep, and is carried by nine main arches, each 82' 10" centre to centre, and a number of subsidiary ones to give a total length of 14 chains.
- 1.3 It is of significance not only because of its ongoing role as an extension of the original Bondi Ocean Outfall Sewer, now 98 years old, but because it is one of the first two large reinforced concrete structures to be built (between 1895 and 1897) in NSW, the other structure being its "twin" across White's Creek about one kilometre further upstream.

2. Engineering Design and Construction Aspects

Although the term "reinforced concrete" is now even a commonplace household one, in those days it didn't exist, and terms such as "ferro concrete", "concrete iron", or "steel concrete" were used to describe any one of a number of patented systems for providing tensile strength in concrete components by the inclusion of metal (usually iron) rods or more flexible tendons such as wire ropes. In his paper (see bibliography), Fraser lists no less than 29 patented systems.

The most famous of these was the "Monier" system used to describe concrete strengthened with embedded metal rods or meshes. Joseph Monier was a Paris gardener who manufactured gardening items including clay and, later, mortar, flower pots and tubs which he strengthened with an embedded mesh of iron wires. In 1867 he patented his "invention", and, over the next five years, took out patents for pipes, arch bridges beams and reservoirs. Monier sold his patents to a German firm in 1879 after which development of his system proceeded apace.

The Johnston's Creek aqueduct and White's Creek aqueduct were the first large reinforced concrete structures to be built in NSW and the method used for their design was the "Monier System".

2.2 Credit for introducing the Monier system to NSW must go to two engineers:-

(1) W.J. Baltzer who was employed in the Sewerage Branch of the P.W.D. from 1885 to 1895. He had received his engineering education in Germany, and on a visit there about 1890, made a study of the application of the Monier system to large works, particularly bridges, consequent upon Monier's sale of his patents to German interests in 1879.

(2) F.M. Gummov, whose firm Carter Gummov and Co, in 1895, held the agency in NSW for the Monier system. The firm retained Baltzer as a consultant even though he was then still employed by the P.W.D. Gummov was an engineering graduate of Melbourne University, and by 1896 had had 13 years practical experience on water and sewerage works.

- 2.3 After 1890 in its program for extending the B.O.O.S. further upstream, the Sewerage Branch of the P.W.D. drew up plans for sewer aqueducts across Johnston's and White's Creeks supported on brick arches, at an estimated total cost of 11,298 pounds.

(In his own estimates, as an "out of working hours project", but within the ambit of his consultancy with Carter, Gummov and Co, Baltzer drew up a proposal using Monier concrete arches supporting a reinforced concrete conduit at an estimated cost of 9203 pounds.

The estimated cost saving was a major consideration in awarding the contract to Carter, Gummov and Co, but as the new method was rapidly achieving recognition overseas and had

attracted the support of Professor Warren of Sydney University, the P.W.D. also considered it appropriate for adoption on the grounds of technological advancement. Late in 1895, owing to severe economic depression, Baltzer was retrenched "with great regret" from the P.W.D. Whether or not his "moonlighting" was a factor in his retrenchment, must remain an unanswered question. There is no doubt about the quality of the structure, however, because, only now, 90 years later, has it been necessary to effect any significant repairs. These are in progress, and consist of the insertion of a plastic line in the flume, the arches still being quite sound.

3. Plans accompanying this Classification proposal

Four sheets of the drawings of "Contract No. 77", two with date 4/2/95 visible, have been filed in the Trust records. Contract 77 covered the Johnston's and White's Creeks aqueducts as being components of "Northern Main Sewer, 2nd Division".

Sheet 1. Street plan of the relevant Annandale and Leichhardt areas.

Sheet 2. Longitudinal section of the "Northern Main Sewer, 2nd Division" between and including the Johnston and White's Creeks aqueducts.

Sheet 11. Elevations of the two aqueducts.

Sheet 12. Details of the two aqueducts.

4. Boundary and Curtilage

No curtilage is involved, and the appropriate boundary for the proposed Classifier is a line around the structure to form a rectangle giving a maximum of 2 metres clear from the external edges of the structures.



Sewer aqueduct over Johnstone's Creek stormwater canal



Johnstone's Creek sewer aqueduct



Exposed reinforcing mesh on the soffit of Johnstone's Creek sewer aqueduct

ANNANDALE		APPENDIX C - National Trust List WHITE'S CREEK SEWER AQUEDUCT		Piper Street, south side Across White's Creek U.B.D. 7-7/F
(Town or District)				
Post Code 2040 Mun of Local Govt Area Leichhardt				
A.C. of J M Collocott Proposal				
Date of September 1987 Proposal				
Suggested Listing Category		(Name or Identification of Listing)		(Address or Location)
CLASSIFIED		Bibliography 1. "The Water Supply, Sewerage & Drainage of Sydney" by W V Aird, Halstead Press 1961; 2. Early Reinforced Concrete in NSW", D J Fraser, PhD, MIE Aust; Transactions of the Institution of Engineers Australia, Multi-Disciplinary Engineering Vol GE9		Owner and Address Metropolitan Water Sewerage and Drainage Board cnr Pitt & Bathurst Streets SYDNEY NSW 2000
Committee (Trust Use)				
IAC				
Council (Trust Use)				
APPROVED CL 2.11.87				
Description Briefly cover the points on the following checklist where they are relevant and within your knowledge.				
Style	1. Introduction and Historical Background			
Construction Use	1.1 In 1859, Sydney had a rudimentary sewerage system of five sewers draining to the Harbour and serving an area little larger than what is now the central business area of the city proper. (See Fig 1).			
Architect/s				
Builder/s				
Date of Construction				
Present Condition	By 1889, this had grown to some ten kilometres of main sewers and 103 kilometres of subsidiary sewers serving 18,000 properties in the Sydney City area, and about 25 kilometers serving 6,750 properties in the suburbs of Darlington, Paddington and Redfern.			
History	The system was controlled by the City Council and continued to discharge to the Harbour until 1889 at which time two major projects initiated by the Government (and constructed by the Public Works Department between 1880 and 1889), were commissioned. These were:			
Owners	(i) An ocean outfall sewer discharging to the ocean near Bondi;			
Boundaries of proposed listing	(ii) A southern system of sewers draining to a sewage farm at Botany			
Reasons for listing				
1. The status of the aqueduct (along with the similar Johnstones Creek Aqueduct) as being one of the first two major reinforced concrete structures to be built in NSW, and amongst the first to be built in Australia. 2. The historical significance of the aqueduct as being a key component of the first extension to the Bondi Ocean Outfall Sewer. The BOOS was completed in 1889 to become the basis of the first of the three major ocean outfall sewers which serve Sydney to this day, and the aqueduct was completed in 1897 only 8 years later. 3. Its position as being a good example of a significant sewer structure which can be seen. The great majority of any major sewerage system is hidden underground but there are places where crossing gullies, rivers or river flats at which the sewage carrying structures can be viewed. The White's Creek Aqueduct is such a case.				
Sketch plan and photos Attach additional photos if any.				

In 1888, the new Board of Water Supply and Sewerage was created, and, in 1889, it took over the old City Council system and the Government's new works. (See Fig 2.) The new works were the basis of the two major sewerage systems which to this day still serve the greater Sydney area south of the Harbour, i.e.:-

- the BOOS - Bondi Ocean Outfall Sewer
- the SWSOOS - Southwien and Western Suburbs Ocean Outfall Sewer

1.2 The White's Creek sewer aqueduct is an original key component of the upstream extension of the BOOS (which was then known as the Northern Main Sewer), and still carries the sewage derived from the Balmain/Annandale areas across White's Creek on its journey to the ocean at Bondi. The externally rectangular conduit has an internal U shape 3' 3" wide by 4' 3" deep, and is carried by eight main arches, each 82' 10" centre to centre, and a number of subsidiary ones to give a total length of 15 chains.

1.3 It is of significance not only because of its ongoing role as an extension of the original Bondi Ocean Outfall Sewer, now 98 years old, but because it is one of the first two large reinforced concrete structures to be built (between 1895 and 1897) in NSW, the other structure being its "twin" across Johnstone's Creek about one kilometre downstream.

2. Engineering Design and Construction Aspects

2.1 Although the term "reinforced concrete" is now even a commonplace household one, in those days it had not been introduced and terms such as "ferro concrete", "concrete iron", or "steel concrete" were used to describe any one of a number of patented systems for providing tensile strength in concrete components by the inclusion of metal rods (usually iron) or more flexible tendons such as wire ropes. In his paper (see bibliography), Fraser lists no less than 29 patented systems.

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..see over

2.3

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On his own initiative, as an "out of working hours project", but within the ambit of his consultancy with Carter, Gummov and Co, Baltzer drew up a proposal using Monier concrete arches supporting a reinforced concrete conduit at an estimated cost of 9203 pounds.

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4. Boundary and Curtilage

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Sewer aqueduct over White's Creek, Annandale



CENTRAL TAREE TRUST LISTINGS

The Trust recently classified its first buildings in the central area of Taree City, the Court House and the former AMP Building.

The classifications follow a recent and very successful survey of buildings in Taree and surrounding towns and villages by the Trust's Historic Buildings Committee in conjunction with the Manning Valley Historical Society.

The survey included Cundletown, Coopernook, Tinonee, Wingham and Mitchell's Island. Further research excursions by the Historic Buildings Committee and other committees are planned for later this year.

TRUST MAN ON SOIL COUNCIL

The Minister for Agriculture, Lands and Forests, Mr Jack Hallam, has appointed the Trust's Environment Director, Mr Chris Pratten, to the newly formed Soil Conservation Advisory Council.

The Council has been formed under the NSW Soil Conservation Act to advise the Minister and the Commissioner of the Soil Conservation Service on soil conservation matters. The Council recently carried out a field inspection of works undertaken by the NSW Soil Conservation Service on sites extending from Kurnell through the Hunter Valley to the Liverpool Plains.

DEVELOPMENT ON EARLY GAS SITE

Trust representatives have been involved in discussions with North Sydney Council on the proposed recycling of the historic North Shore Gas Company site at Oyster Cove, Waverton. Under a current redevelopment proposal, the site will be redeveloped for residential and community uses in conjunction with a commercial marina.

The Trust hopes the oldest and most imposing structure, a large harbour-side coal bunker, can be adapted for use as a commercial facility or for housing.

INTEREST IN TOWN HOUSES

Members have shown strong interest in two inner-city town houses recently offered for short-term letting by the National Trust.

The two residences, which together comprise the large terrace house at No. 7 Agar Steps, adjacent to the Trust Centre on Observatory Hill, were advertised for the first time in the June issue of National Trust Magazine.

"From that one ad, members have been booking as far ahead as mid-1988," the Trust's Real Estate Officer, Mr Mark O'Neill, said early last month.

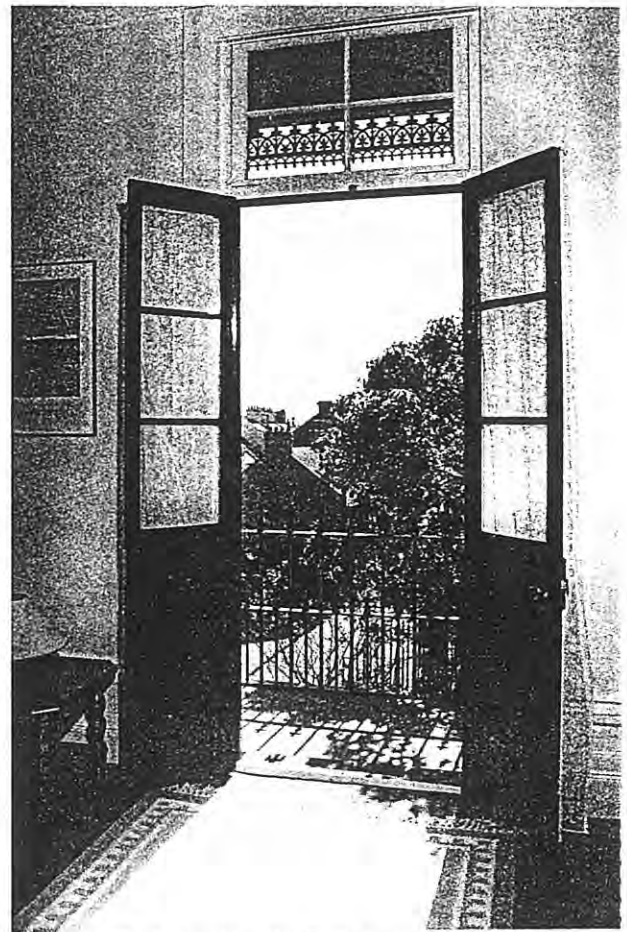
"This confirms the success of the Trust's new policy of letting appropriate properties for short-term business and holiday visits.

"We started almost eighteen months ago when we advertised the Old Rectory at Berrima in the Trust Magazine. The response there was astounding. Within a short while this pleasant cottage was heavily booked through until 1989.

"In the light of this experience the Trust is now looking at several other of its properties, to see if they too might be put to this use."

Mr O'Neill said the results so far were particularly pleasing as the short-term rentals produced relatively high revenue to assist the maintenance and upkeep of the property, and gave members access to distinctive old buildings in interesting locations.

Each town house at 7 Agar Steps has three bedrooms, a modern kitchen and bathroom, barbeque facilities at the rear and balconies with northerly views of The Rocks and Parramatta River at the front.



A view of Old Sydney from the Trust's terrace house at 7 Agar Steps, Observatory Hill.

They are both comprehensively equipped with dish washers, microwave ovens, colour TVs, washing machines and clothes dryers.

Tariffs range from \$300 a weekend to \$500 a week for each unit. For further information, contact the Trust's Real Estate Service on (02) 27 5374.

more unusual inspections: a survey of some of the structures associated with the city's early sewerage system.

The inspection was extremely well attended, with more than thirty participants.

Sites inspected included the Johnston's Creek and White's Creek aqueducts at Annandale. The graceful arches of these imposing structures built between 1895 and 1897, were the first large reinforced concrete structures built in NSW.

MR CLIVE LUCAS

Mr Clive Lucas, a member of the Trust Council for 14 years and a Vice-President in 1986-87, has not nominated for re-election this year because of the pressure of work on his architectural practice. He has said he will seek re-election to the Council at the earliest possible opportunity.

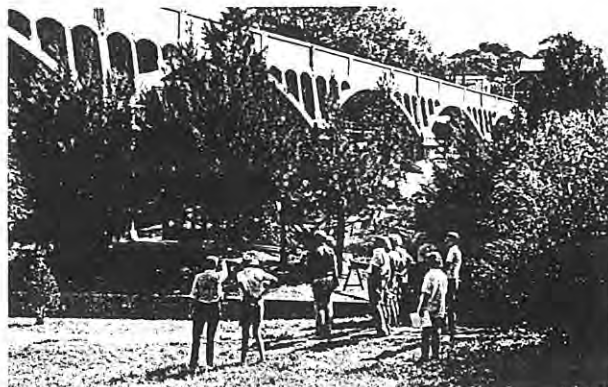
GROUP SURVEYS EARLY SEWER STRUCTURES

Members of the Trust's Industrial Archaeology Committee and representatives of the Sydney Water Board recently undertook one of the

BONDI PROPOSAL POSES THREAT

The Trust is alarmed at a proposal for a 450-room hotel on a site bounded by Spring, Denison and Ebley Streets at Bondi Junction.

The proposal would effectively demolish the three-storey former Forward Boot Factory, which is classified by the Trust, by enveloping it totally (except for the facade of its ground floor). It also fails to take into account the traditional street pattern and the scale of terrace housing in the adjacent Mill Hill Conservation Area



The Trust — Sydney Water Board survey party at the sewer aqueduct over Johnston's Creek at Annandale.

There is more to heritage listing than beauty.

THE GLEBE May 1988

THE inner city boasts four of the 139 NSW items listed on the National Estate register by the Australian Heritage Commission.

Places on this list are not always beautiful historic houses and scenic wonders.

Often they appear to be unexciting engineering works, such as sewerage aqueducts and railway bridges.

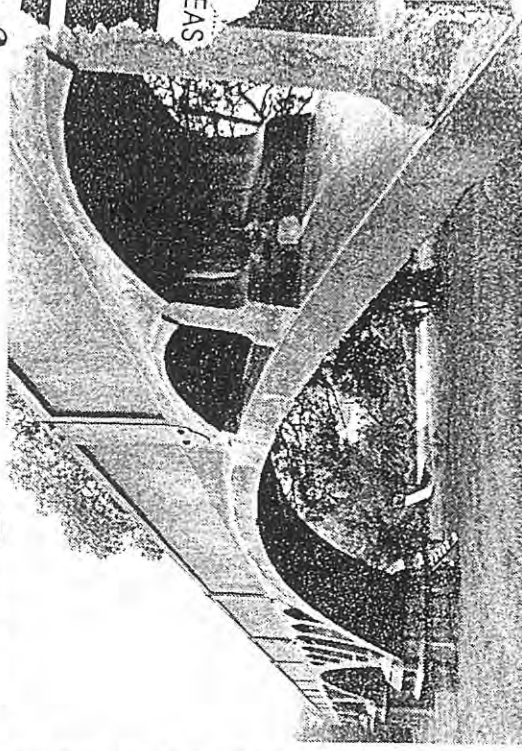
The four inner-city items are: Wollie Creek sewerage aqueduct; King George V Memorial Hospital, Camperdown; Glebe Island Bridge and; the Whites Creek sewerage aqueduct.

Each is considered to be a significant technical achievement.

The Wollie Creek aqueduct is the sewerage main crossing Wollie Creek, which is a tributary of Cooks River at Arncliffe. The Heritage Commission said the aqueduct, built in 1896, was included on the register because it was an important part of the history of Sydney's early disposal system. The series of 17 brick arches over the creek plain were finished with glazed bricks and carefully detailed mouldings and decorations. The large metal beams for the sewerage line were fabricated on the site.

Glebe Island Bridge is significant because it was large for its period of construction. The bridge, built in 1903, was said to be provided with the fastest and most up-to-date swing span in the world. The bridge is in its original form and in good condition.

King George V Memorial Hospital is one of the first



WHITES Creek sewerage aqueduct.

"modern" styled hospitals in brick and stone. It was built in 1941. Its architects, Stephenson and Turner, wanted to introduce clean European styling and modern hospital design principles into Australia. The architects were awarded the 1941 Sulman Medal for the building.

Whites Creek sewerage aqueduct, built in 1896, is a reinforced concrete construction. The design of the aqueduct, with the waterway supported on minor deck arches and spandrel columns plus the use of slender, flat main arch ribs, is unique for an Australian concrete bridge of this age.



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01/10/88

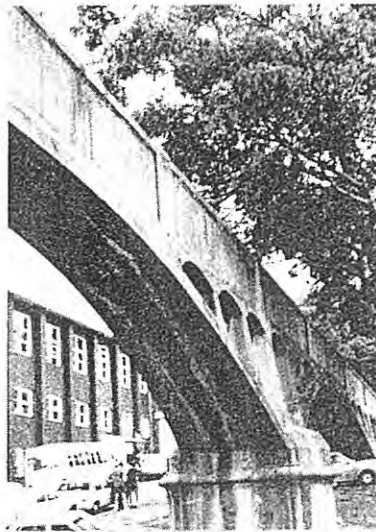


Sewage and heritage mix at Johnston's Creek

Two years ago the Monier arch sewer aqueduct across Johnston's Creek in Annandale, Sydney, built in 1896, was fitted with a PVC liner to prevent seepage caused by porosity of the aging concrete. Now the nearby White's Creek aqueduct is also to be lined, but with a more advanced material.

According to retired Water Board archivist Noel Thorpe (stated in the new book *Sydney: From Settlement to City*) both aqueducts were the first constructions of their type in Australia.

Retired Water Board engineer John Collocott wrote a report on the aqueducts in September 1987. His detailed history and technical description of the structures influenced the National Trust to classify the structures later that year. Collocott said the aqueducts were built using steel reinforced concrete. *The Johnston's Creek sewer aqueduct was built in 1896. It is one of Australia's oldest reinforced concrete structures*



This part of the aqueduct shows evidence of past seepage and concrete spalling

forced concrete developed by the French inventor Joseph Monier in the early 19th century. He said the term reinforced concrete was not used at the time.

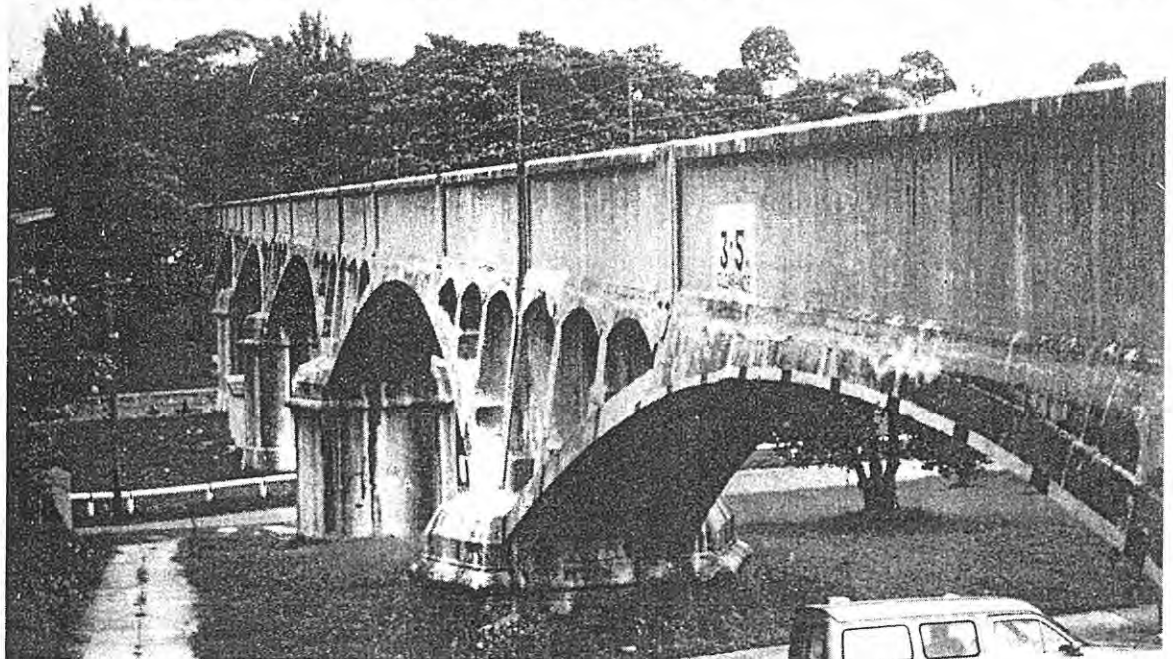
"Terms such as ferro concrete, concrete iron or steel concrete were used to describe any one of a number of patented systems for providing tensile strength in concrete components by the inclusion of metal rods (usually

iron) or more flexible tendons such as wire ropes."

He said the Monier system was used to denote concrete strengthened with embedded metal rods or meshes. Monier was a Paris gardener who used iron wire mesh to strengthen flower pots and tubs which he manufactured. In 1807 Monier took out patents on his invention and over the next five years patented applications of the system to pipes, arch bridges, beams and reservoirs. In 1879 Monier sold his patents to a German company. Collocott pointed out that the NSW Public Works Department engineer who introduced the Monier system to Sydney was a W J Baltzer, who had received his engineering education in Germany, and on a visit there about 1890, made a study of the application of the system to large works, particularly bridges.

The aqueducts were built as part of extensions to Sydney's first major sewerage scheme which originally served the city, eastern and southern suburbs. These first systems known as the Bondi Ocean Outfall Sewer and the Southern Outfall Sewer (which drained into a sewage farm near the present Sydney Airport) were completed in 1888. The extensions westward of the Bondi Sewer completed in 1898 serviced the suburbs of Glebe, Annandale, Lilyfield and Balmain.

— Bob Jackson



WESTERN SUBURBS SEWERAGE

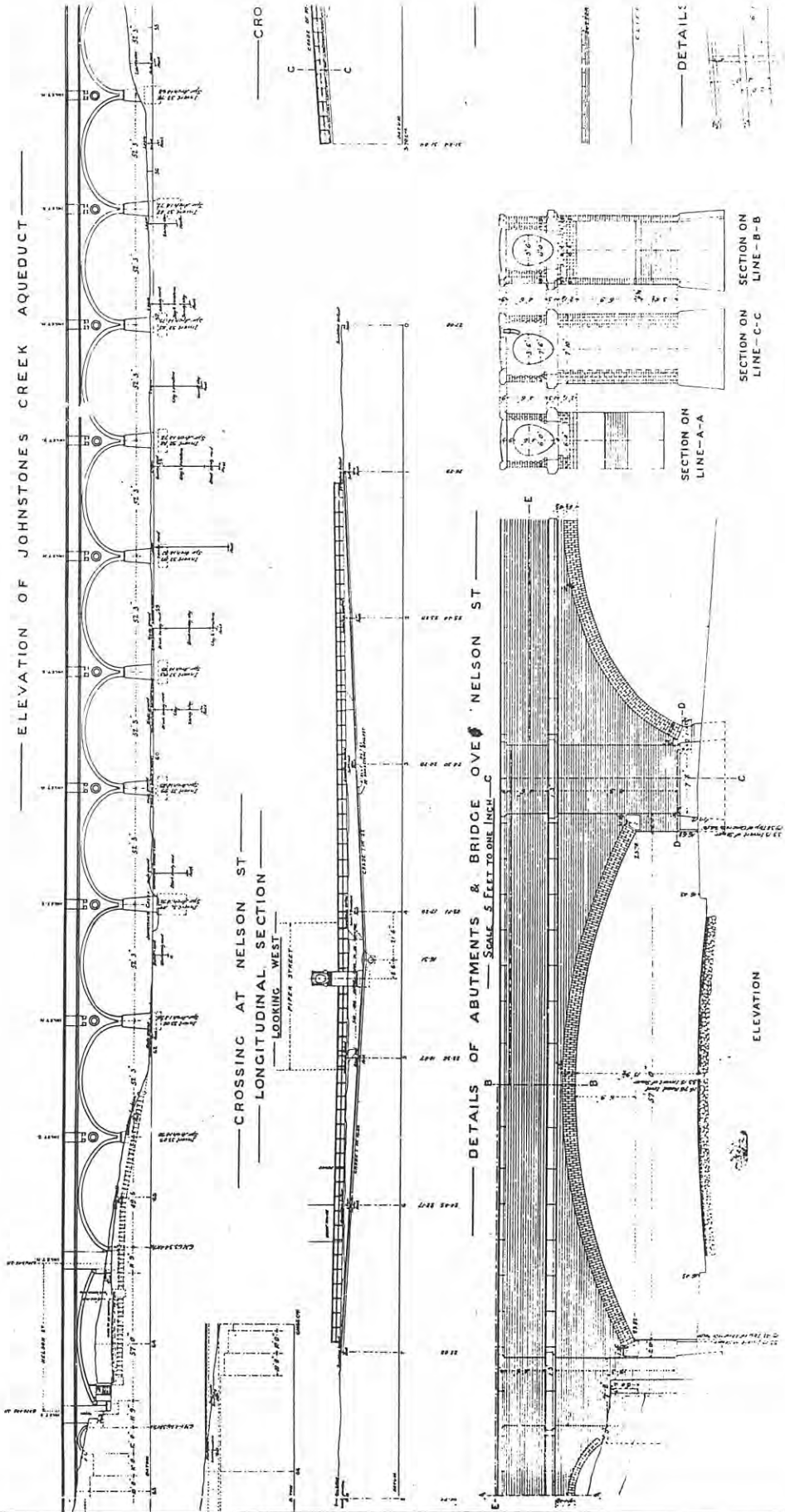
NORTHERN MAIN SEWER 2ND DIVISION

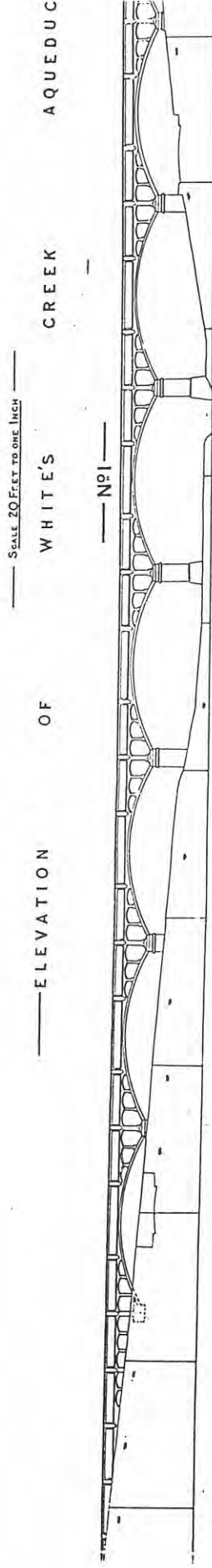
ANNANDALE & LEITCHHARDT

DETAILS OF JOHNSTONES CREEK AQUEDUCT

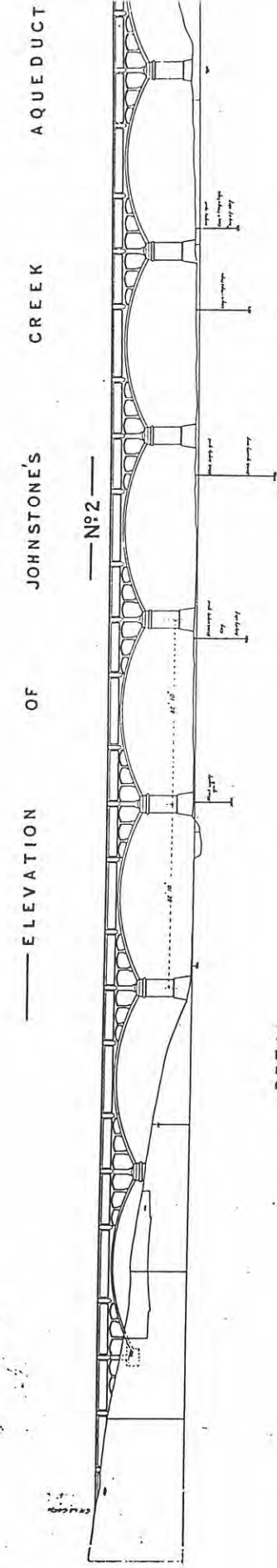
SCALE 20 FEET TO ONE INCH

Brick arches
were the
original scheme

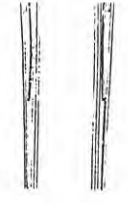
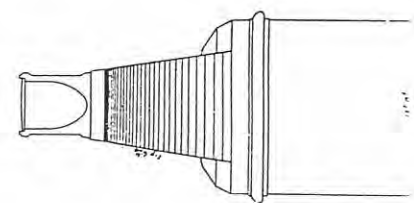
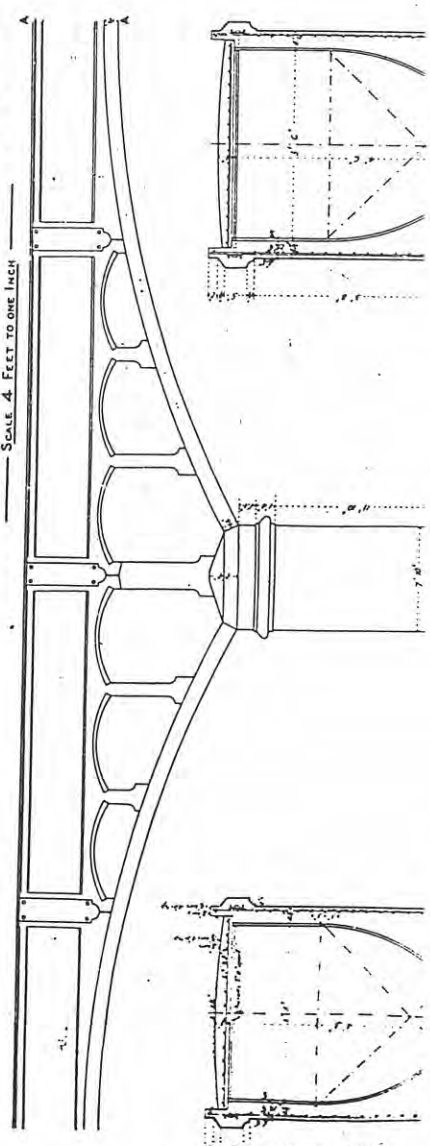




The Monier arch scheme



—DETAIL OF PIER & ARCH—
 SCALE 4 FEET TO ONE INCH —



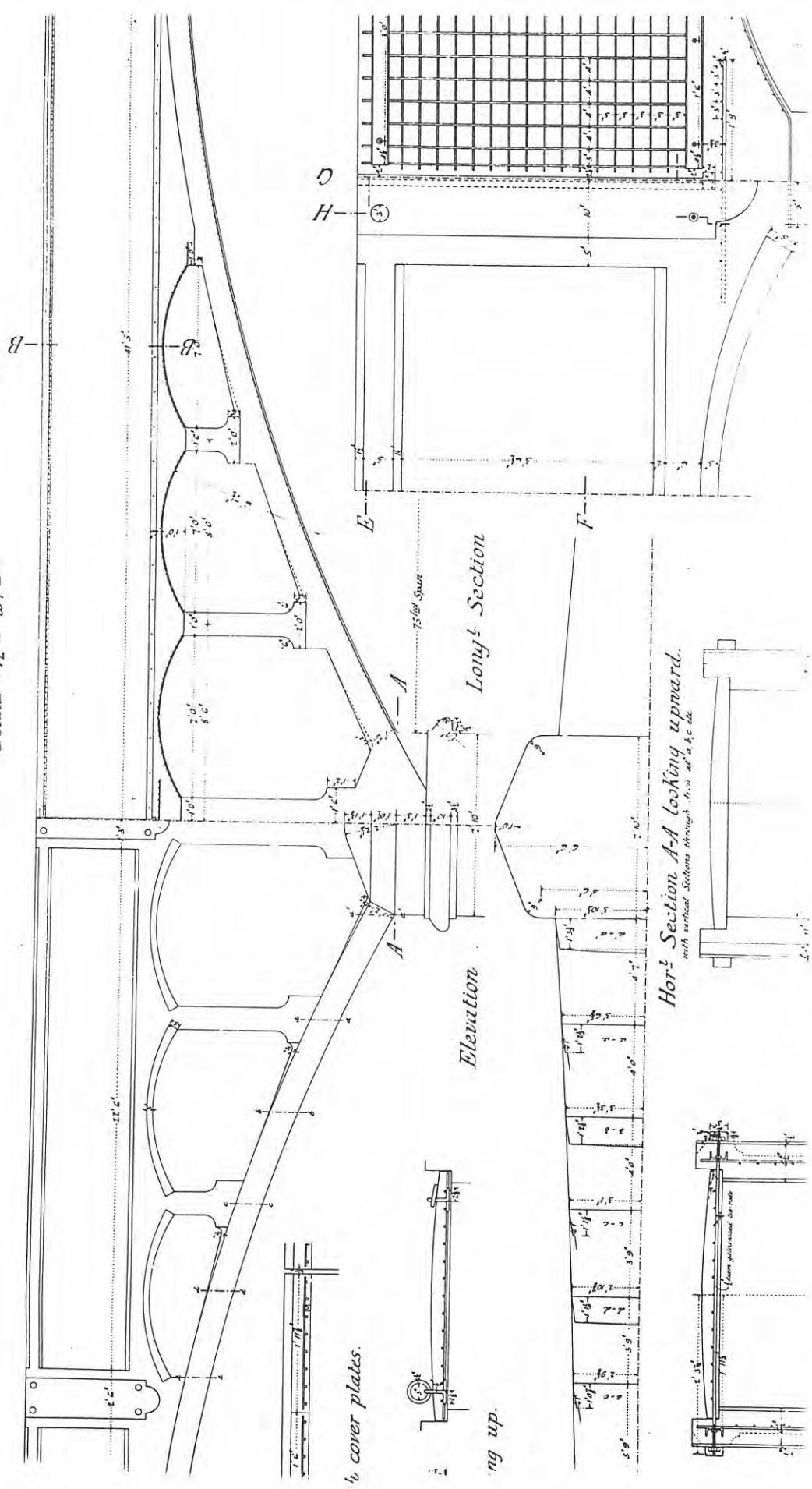
— Northern Main Sewer: —

Monier arch details

— *Contract No 77.* —
— *Details of Aqueducts.* —

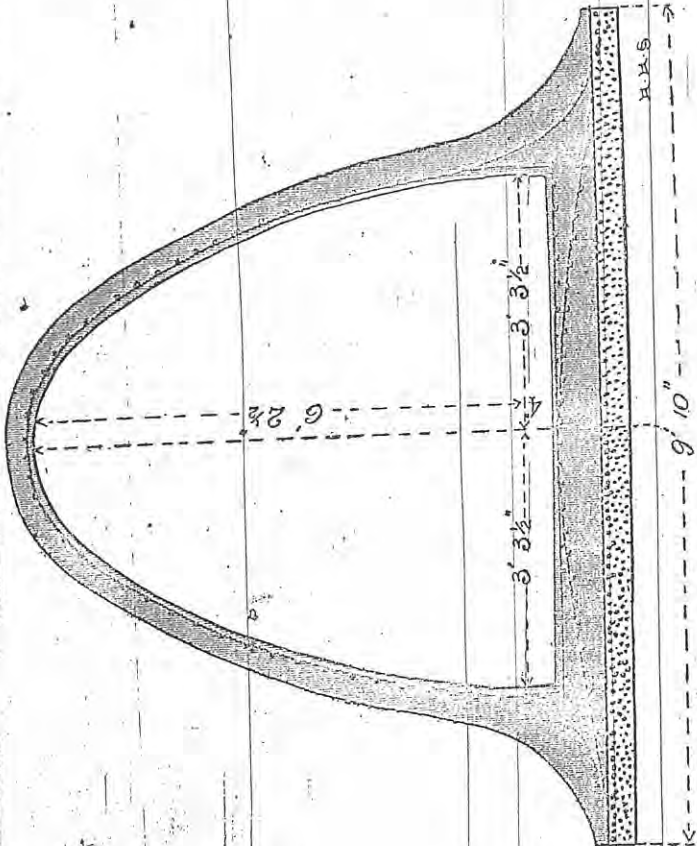
Scale - $\frac{1}{4}$ inch to 1 foot.

Details - 1 4 inch to 1 foot.



The Chinese Revenue System.

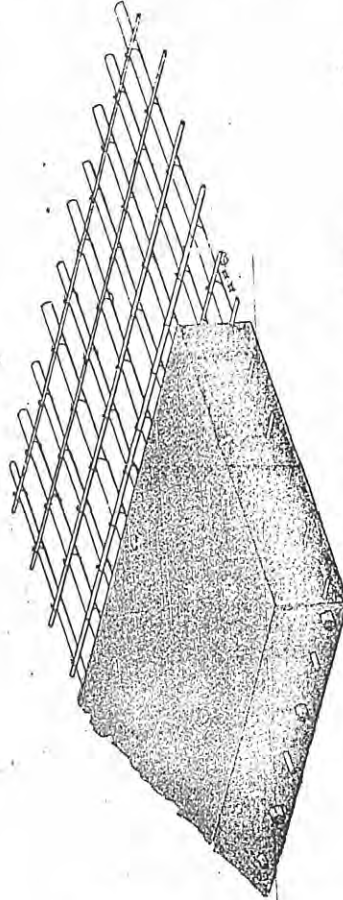
Mr. Allen, the British Consul at Fuchau, in his last report on the trade of that port, says that an obstacle to the development of commerce in China, less easily remedied than bad roads, is a fault, not to say, an utterly rotten and corrupt system of collecting revenue, wherein the vested interests involved are so enormous that nothing short of the reform of the whole fiscal arrangements of China can set it right. Although the evils of this system are patent everywhere in the Empire, there are two places where they are seen in their most aggravated form. One is Canton, the other Fuchau. The system of farming the taxes, or, at least, making the official in charge of them remit a certain sum every year, while he puts the balance into his own pocket, insures the largest possible collection at the greatest possible cost and the least possible benefit to the Government. It is said that the cost of collecting likin is 70 per cent. of the total sum realised. The tax farmers are not low class pariahs like the publicans of Judea. On the contrary, a tax farmer may be, and often is, a mandarin of the highest rank. In Fuchau there are four separate establishments levying taxes on merchandise, each one competing with the others, and looking on the revenue collected by them as a loss to itself. These are: (1) The Maritime Custom House levying duties on all goods imported or exported in foreign bottoms or in Chinese steamers. These press lightly on trade, except in 1858, was which pays 2.50-tael a picul, which in 1858 was supposed to represent an ad valorem duty of 5 per cent. This, then, makes the average value of tea 30 taels per picul. It is now only 15 taels, so that the proportion of duty has risen from 5 per cent. to 16½ per cent. Indian and Ceylon teas pay no export duties, so that this impost alone is enough to handicap the China trade. (2) The native Custom House levying



Section of a Monier Arch.

"Monier" Arches.

In the course of the inquiry into the administration of the Public Works Department by the Royal Commission now sitting much mention has been made of the substitution of the "Monier" principle of building arches, bridges, &c., for the old familiar style. This patent is not understood by the ordinary public, and by courtesy of Mr. Hickson, Under-Secretary for Works, we are enabled to illustrate, and give some explanation of it. This method of building bridges is really to use cement upon an iron framework or lattice, as shown in one of the plans now published, while another illustration shows a section of an arch, the black-lets representing the ends of the iron bands. The third illustration, giving the picture of the completed work, is of a bridge near Ingolstadt, in Prussia, in which the span is 50 ft. 11 in. and the thickness at the "crown" only 2½ in. Several arches were constructed at Forest Lodge, near Sydney, with a span of 24 ft each, and a thickness at the crown of 3 in. and these all stood most thorough tests as to strength. The materials used in this method of construction are (1) Portland cement, (2) sand, or sand blended with gravel or broken stone; and (3) iron rods bonded together so as to form a strong building construction, containing strength and durability, with elasticity and resilience. It was at first cautiously applied to bridges of small spans, and as it was found to be unaffected by vibra-



Framework of a Monier Arch.

ence on it, the only perishable component—iron—being protected by the cement mortar, which in itself improves with age, and does not deteriorate like most building materials. In addition to the salient points above briefly referred to, the uses to which the system could be applied are infinite, and cannot be more than touched upon in such a necessarily brief sketch.

the Imperial family. He and two other functionaries, the Superintendent of Customs, or "Hoppo," at Canton, and the Superintendent of the Hual-an Custom House, all Manchou officials, are the special purveyors of the Court. The Tartar-General collects at Fuchau alone 100,000 taels annually, of which 30,000 taels are levied on timber; it is not known how much he gathers from the other Custom Houses in the province, but he is supposed to make 150,000 taels a year for himself. It is not, Mr. Allen explains, the actual amount of money which the native Custom House levies on merchandise that causes it to be such a hindrance to the development of trade; it is the jealousy of the foreign Customs revenue. One of the principal needs of the China trade is the use of small native steamers to go to non-treaty ports, and to act as feeders for the lines of steamers which connect China with foreign countries. This is the plan successfully adopted in Japan; but it is not possible to do this in Fuchien province in the face of the opposition of the Tartar-General and his dependents, who would lose their revenue on the junk-borne cargo, for steamers pay duty at the Maritime Custom House only. (3) The Likin Office: The likin tax, originally a temporary war tax, is supposed to provide for the wants of the provincial Government, and is under the control of the provincial treasurer. The head office at Fuchau produces annually 700,000 taels, the other offices in the province making up the total amount to 1,200,000 taels or more. The tax is a universal excise duty, from which nothing produced in the country or imported from abroad is exempt. It is only a peaceably-disposed people like the Chinese who would submit to a tax which must be almost as burdensome as the tax of the tenth penny imposed by Alva on the inhabitants of the Low Countries. Even in China the imposition of likin occasionally leads to riots. The likin duty on tea is nominally 2.50 taels per picul but additions bring it up to nearly 2.80 taels. The tax for reasons known to the officials, is divided into five items, called original dues, likin dues, expense of collection, military contribution, and "loss on touch of silver," all of which vary in amount. To these have to be added a ferry toll or duty on all teas from the north, and a tax of 3c "for benevolent purposes" on teas coming from the districts to the west, and one or two extra tolls, so that the total amount does not fall short of 2.80 taels. If the value of tea is taken at 15 taels per picul, with the export duty it has to bear taxation to the amount of 5.30 taels, or about 35 per cent. ad valorem, before it leaves China. It may be asked why transit passes are not taken out, which would enable the merchant to bring the tea to the port on a payment of 1.25 taels per picul. The native dealers and growers are afraid of official opposition and European exporters find it impossible to make the necessary arrangements. (4) The Lo Shui or Octroi Office: This has seven branches, which collect annually 30,000 or 40,000 taels on goods taken into Fuchau by road. Like the likin, it is under the control of the provincial treasurer.

Pearce's Creek Dairy Company, Alstonville, treated 26,972gal milk for 10,945lb butter during September. Suppliers were paid 8½d per lb for butter fat, equal to a fraction over 3d per gallon for milk. The continued dry weather is causing a great scarcity of grass in the Wollongong district, and is having a very injurious effect upon dairy cattle, materially diminishing the yield of milk. Many dairymen are compelled to purchase large quantities of bran and fodder to keep up the condition of their herds.

In addition to the salient points above briefly referred to, the uses to which the system could be applied are infinite, and cannot be more than touched upon in such a necessarily brief sketch.

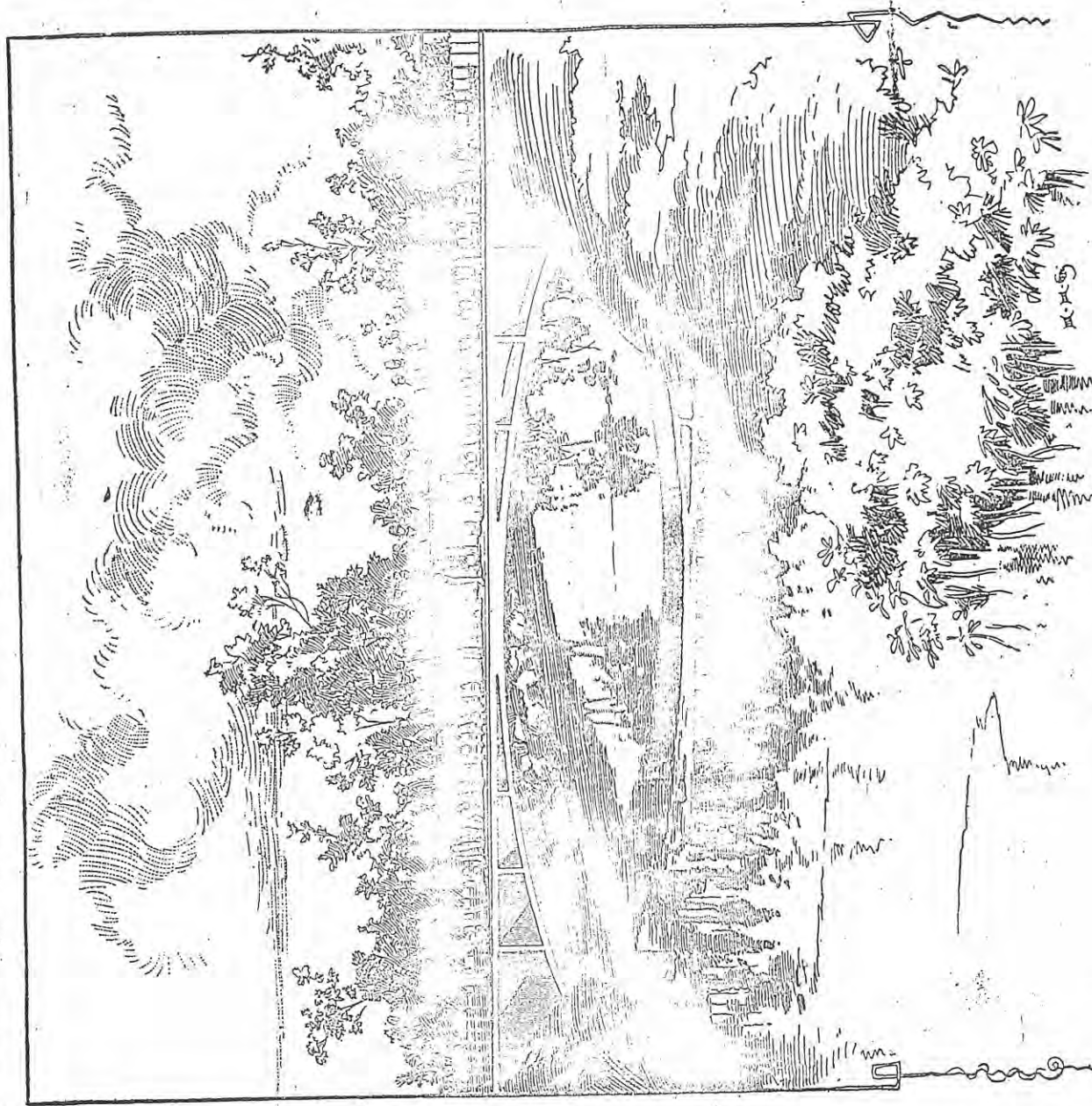
rods bonded together so as to form a strong unifying construction, containing strength and durability, with elasticity and resilience. It was at first cautiously applied to bridges of small spans, and as it was found to be unaffected by vibrations, varying loads, or changes in temperature, the system was more generally adopted with signal success in the erection of bridges, culverts, pipes, reservoirs, flumes, buildings, domes, floors, walls, fortifications, &c., and other constructions where the conditions of fire-proof, water-proof, strength, durability, elasticity, sanitary or other reasons are necessary features, which, combined with its easy manipulation, cheapness, use of ordinary trade requirements, make it a building material generally applicable to city or country.

The principle of construction is to increase the strength of cement and its mixtures by the judicious insertion of iron in such necessary places as to insure the utilisation of the full properties of the cement mortar, and to get a construction of great strength, combined with elasticity and durability, at a cheap initial cost, with a minimum of maintenance.

The system of construction consists of iron rods placed longitudinally and laterally to form a mesh or lattice. The sectional area of the rods, and size of lattice used, vary with the requirements of the structure, and are ascertained from formulae founded upon practical experiments. The rods are held together at their intersections by thin wire, sufficiently strong to hold them in position during the process of packing the cement mortar around them. Ordinary trade lengths of iron are used, breaking joint at various points, the joint consisting of an overlap. The lattice is erected on the centre line, and the cement mortar is pressed through and around the lattices in convenient thicknesses and well rammed. The mortar in setting shrinks, and gets a firm grip of the iron, and as the adhesion between the two materials is equal to the cohesive strength of the mortar, and the physical and chemical properties of this combination favorable, the whole forms a homogeneous mass, which remains unalterable under vibrations or other exterior forces. The lattice work is calculated to take up and distribute any tension the structure is likely to be subjected to, and to give elasticity to the body. The longitudinal bars take up the direct strains, and the lateral bars distribute the stresses over them. It has also been proved that the encasing of the iron in the mortar removes all risk of the iron oxidising, as cement is one of the best preservatives of iron known, chemically forming a silicate with the iron, and freeing it from rust.

By the use of this system a structure can be built having a maximum strength with a minimum dead weight as compared with brick and stone structures, which is a very important factor, especially on bad foundations. The system also presents to the engineer and architect a material both plastic and flexible in erection. The nature of the materials allows of its use under all circumstances as it adapts itself to any shapes or forms required by the architect, as in cornices, ornaments, decorations, &c., or by the engineer for pipes, culverts, &c. Where time is valuable the Monier arch is a particularly important acquisition. The centres can be quickly erected and removed, and as the cement mortar is only a thin body, it hardens very quickly, and the structure can be brought into use at once. As an example of this the case is quoted of a bridge built at the Bremen Exhibition (Germany), where a span of 13 ft and 10 in thick at the crown was built in 36 hours. The maintenance of these structures is very slight, as the action of the air, water, earth, and fire have but a small damaging influ-

before, the Governor-General. The present incumbent of the post has been Governor-General of the Hukwang provinces, and afterwards military Governor of Manchuria. He is said to be a relation of



A Completed Monier Arch.

1897 Legislative Assembly NSW
Public Works Inquiry Commission
Report of the Royal Commission appointed 21 May 1896

NSW PP 1897 V6 held at NML

Allegations by Mr Varney Forbes M.A. concerning Mr. R.R. Hobson, Under Sec Pub W, in his handling of contracts held by Carter & Co., ~~by~~ Carter, Gummow & Co. Favouritism, insufficient bond, incompetence, allowing defective work, violation of terms of contract. Also George Maddison, Peter Ervine, F.M. Gummow, George Forrest, James Gillan.

Commissioner's opinion was that none of charges proved, officers & Dept PW exonerated.

[Favouritism = C & G Co. tenders without a recall of tenders and giving them
(Disfavors) exclusive advantage to secure the contracts.]

R. R. P. Hobson

July 1 1889 Comm Roads & Bridges, En C Sewerage, succeeded late W.C. Bennett

April 1 1895 En C Public Works

March 5 1896 Under Sec PW

C. W. Darley

Jan 1 1889 En C Harbours & Rivers, vice E.O. Merrially

April 1 1895 Pres W & S B, En C Sewerage Constr Br

March 5 1896 En C Public Works

Appendices p.33

Hobson minute - "Monier system of concrete arching patented in Colony by Carter & Co. Reduces costs by 50%. Pay royalty of 15%. Culvert just complete on Parramatta Rd very satisfactory" 18 July 1894

Letters Patent, Appendices p47-49

Description of monier system. John Carter, David Snedgrass, William Baltzer.
Registered March 1 1893, but issued Nov 3 1892.

NB the name "Monier" not used in the patent.

Company Partnership p50

John Carter, David Graham Snedgrass, George Forrest, Frank Moorhaus Gummow,
James Gillan, George Maddison, Peter Ewing.

~~Directors as~~ ~~the~~ Carter, Gummow & Co

Monier culvert, ^{at Stratfield} Burwood, App p69/

lists of vouchers & costs
see later evidence by W. A. Smith.

p81 54' x 6'-6"
{ 9" brick arch = 4 1/2" monier arch £22
{ 14" " " cost £33
(I am confused about this costing)
see later Symonds evidence

Speedwell costs, App p74/75

Dept estimate £11,203

Monier estimate £7,988

John Young's (Contractor) estimates

Monier System, App p95-104

mostly same as report with SRA, information supplied by Carter
and by Baltzer. p103/104 have some calculations dealing with
formulae for monier beams and plates. ~~the~~ (maybe worth a photocopy)

Annandale Aqueducts, Contract N°77, App p1-25 Specification

May 7 1896

MWS&DB have supplied copies of drawings
of the monier arch aqueducts to me.
Contract N°77 sheets 11 & 12

p221 Burwood culvert at foot of Wentworth Road

Main Report, P XXX VI & VII

brief description of purpose of res in beams/girders/plates, vertical load produces tension at lower face hence place longitudinal bars near the lower face.

Arches rely on compression but a load moving across the arch causes bending in other parts of the arch, sometimes flattening the curve of the arch, sometimes increasing the curvature of the arch. The iron adds to the compressive strength of the arch by the added quality of a girder. Loads can be imposed at any point.

P XXX VIII

Mr. Baltzer draughtsman Sewerage Constr Br of Works Dept, good training in engg in Germany, information from brother on Monier system. Contacted Carter hence the letters patent. Baltzer prepared a treatise on the system with illustrations, shown by Carter to others incl Hickson. PWD officers expressed strong favour of the system but doubted if sufficient expert knowledge in the Colony.

(NB) patent same as the Monier system, so should be free to public use.

May 1894 experimental culvert completed in July, tested by a severe strain (load).

Hickson offered 15% royalty.

P XXXIX

Mr. Bagge PWD says Monier system was common knowledge for some years in NSW — patent could be invalid

Main Report p x1

monier schemes investigated by Bagge for Botany Sewage Farm. Baltzer had knowledge of monier system so did the designers, Feb 1895. Doubts about Baltzer being PWD officer and holding interest in the patent.

Contract N^o 77, Annandale Aqueducts, people of the suburbs had an interest in preventing disfigurement of these depressions, Johnstone & White's Creeks.

PWD scheme was for elliptical brick arches. 48 ft spans. MWS & DB have supplied copies of sheets 4, 6 & 7 for Contract N^o 77.

p x1i

Tenders called March 13 1895. Botany Sewage Farm scheme for monier arches not used, so patentees decided to modify design for use at Annandale hence use Monier system on a large scale. Plans prepared by Baltzer, out of office hours. Tender not submitted in usual manner hence subsequent objections and one reason for the Inquiry. PWD estimate £22037, CG & Co £15500, next tenders £16418 & £20935.

His signature on sheets 6 & 7 of Contract N^o 77 4/2/95 brick arch aqueduct

Bagge reported Monier tender because of its "speciality" and lack of confidence in ability of those involved to carry it out properly.

p x1v

But Mr. Hickson had a firm belief in the system and was anxious to give it a fair trial. Scheme would be successful, strong and graceful. Anxious to put in to practice a new departure in engineering.

Main Report p x/vi

Experimental orders at SE corner of Johnstone Ck aqueduct, other tests overseas, use of Monier system was far from speculative + Burnwood culvert

p x/viii

Changes relevant to Contract N^o 77 not substantiated.

Minutes of Evidence

p 634

25 Sept 1896

F. M. Gummons - C.E. Melbourne highest degree 13 yrs in practice
at 21 worked on Bondi sewer, salary £520 per year
1886 ~~contract~~ tendered for Govt work at Belmore Park, not successful
1887 contracts for Hyde Park sewer, excavation at Potts Hill reservoir and other sewer lines
1892, Aug, first contract with Carter & Co for Adelaide contract
Gummons & Gillon separate firm from Carter & Co
1893 first contract N^o 69 at Morrichville with Carter, Gummons & Co

p 647 Sept 28 1896

Estimate details for Contract 77 £14 677
tender price £15 500

p 648

Retention money for Contract 77 seems to be £5000

p 650

Baltzer got 2½% of cost of Monier portions of contracts

Baltzer had gone to Europe to get more information about the Monier system, Berlin for hydrations etc

Evidence p 581

William Julius Baltzer

Sept 16 1896

engineer, employed by CG & Co, previously Govt service Sept 1884 to March 1889, then Dec 1889 to Oct 1895 when retracted £335 salary, joined CG & Co Sept 1895.

Had been to Germany after absence of 14 years visit relatives and get details of Monier system or other works that could be useful to the Colony.

p 582 NB Baltzer says line of pressure for Annandale ditches lies within middle $\frac{1}{3}$ hence no need for grill of iron.

[The Commissioner mentions the fact that full aqueducts do not give rise to bending in arches]

Conditions & work supervision much the same in FWD as in Germany. First bcs in Austria contractors had to leave 10% deposit and maintain structure for 3 years.

Patent held by company, not M. Monier

*) to be completed p 582 etc.

~~58~~ Another designer, Mr. Kern.

Baltzer used theory of elastic arch, Schieffler's theory.

Other designers still used common theory of voussoir arch.

Baltzer took photos of monier works in Germany and wrote a treatise.

Bagge was prejudiced against Monier system, wanted to stick to old ideas, no new fancy-work

Worked on design & drawings for Contract 77 at home. Carter & Snodgrass were friends of Baltzer. + ^{practical} experience. Carter made tests at North Shore, and at Forest Lodge.

some personal animosity between Bagge & Baltzer.

Comments for Contract 77 are Germania & Hennessy brands from Europe

Baltzer ignored iron grill in calc strength of the arches.
Arch does not act in any sense as a girder.

Equal load throughout

Single grill of iron

Arches could stand up without it

Grill makes arch more elastic

p 585 Note from Mr. Bennett 11/1/1889

Baltzer employed last 4y 3m in Sewerage Dept, very useful in doing details, neat, intelligent, industrious, steady, well-behaved, gives promise of success in his profession.

Similar remarks from Bagge 11/1/1889

Hickson 3/5/1895

Baltzer employed for 10 yrs Sewerage Constr Br, designed large works, resourceful & capable officer. Great regret to have to retrench him.

p 586 Contract 77 arches, max strain 300 psi whereas the Monier Co in Europe allows 560-660 psi.

To receive 2 1/2% of profits from contracts actually obtained.
Salary of £250 with Carter, Gummow & Co.

p 589 Good for Dept to accept substitute tender and so get valuable experience in this form of construction

Baltzer has a relative in Germany who is a Professor at the Technical School, Berlin.

A brother teaching Zoology

1892 letter from Morion Company offering to afford Baltzer every information.

Baltzer's book took a great deal of time to compile.

P170 of Evidence, W.A. Smith District Engr PWD
29/6/1896

(of Burnwood) Strathfield Arch - first one built here, Smith had proposed a paper to the Royal Society, not published. Built in July 1894, Main West Rd, Strathfield (Experimental arch by C.G. & Mary 1894)

→ details of system and its advantages

P171 5'-6" span 54 1/2' long cost £114 brick arch £165
14 3/4 cys see also J. Symonds evidence

P173 of Evidence Norman Selfe C.E. M.I.C.E.
1/7/1896

Had examined ~~the~~ Patent N° 4084 3/11/1892 in name of Carter, Snodgrass & Baltzer.

Invention = lattice of iron bars & being tied at their intersections
General use of embedded iron was already known and practised.
so patent confined to use of cross bars & tied at crossings

Govt could freely use the system with their own form of tying at the intersections

p661 of Evidence

F. M. Gummow

6/10/1896

The Book — appeared in 3 versions

1. a smaller book, first document on the system in 1893, Appendix 58, a 2-page report by Baltys.
2. the second, a longer book
3. a still greater improvement, got out at end of last year (i.e. 1895)

[Appendix 57 could be book N°2
The SRA book could be book N°3.]

Evidence of W. H. Warren

Prof of Engg at SU

17/7/1896

p264 a general report to the Commission about concrete in combination with iron or steel. Used in last 50 or 6 years for great variety of purposes. - - - - -

Europe has chiefly used the Monier System

Other methods, mainly in America but also used in Europe

Ransome — concrete & twisted iron

Mellon

Sidero Cement & Bordenave System

Wünsch.

p266 References — The Engineer April 10 1896 p364

on Monier System

American Engg News 2/4/96 p220, 9/4/96 p238

ICE CXI p413 CXVII p407 CXX 392

ASCE April 1895

Test slabs made at Arncliffe and sent to Uxbridge by carts.

p267 Women had checked the Annandale orders, full to the brim, twist as strong as ordinary design, wonderfully light structure. Would not like to use such thickness without the iron network.

Women watch work at these aqueducts, first-rate work

Worren considered that a 3-yr guaranteed was no risk to the country.

Monier fests Oct 26 1894 slates

p270 Warren has seen some Morai work in America while on a recent trip.

p272 Warren had not test Monica ardes

P 319 Warren Leckie estimates for the Annandale arches
C 660 £15 565 Dept £15 789 then his
own as a contractor £17 660.

NB £6 362 was cost of work in the tunnels.
so cost of aqueducts = ~~15 565~~ ~~15 565~~ - 6.362
£ 9 203

Dept £9 427 for Monier arches
£11 297 by Warren as a contractor.

Baltzer & Jummow were the engineers
Carter, Forest, Snodgrass, Gillon, Maddison and
Ewing were contractors.

p221, 227, 315, 375

J. Symonds
PWD Road Superintendent
Parramatta District.

Evidence relevant to Burwood Culvert.

see also earlier note about App p69 & 81

General thrust of Symonds' evidence was that for small culverts (such as at Parramatta Rd, Burwood/Stretfield), the monier system offered no advantages.

Has contended that Smith's costs were wrong.
Brick arch cheaper than monier arch

Instead of monier arch being 50% cheaper it was actually 100% dearer

p375 12 Aug 1896

Symonds presented estimates (App p81) for costs of 2 brick arches, 9" & 14" brickwork.

Noted earlier @ £22 & £33

NB there was a fortnight delay, the men were merely preparing stone and yet still costed against the monier arch.

NB Symonds figures of £22 & £33 seem to be only for the material. ~~See~~ Compared to other estimates, there's no allowance for labour, centring etc.

Conclusion - on basis of straightforward continuous construction
then Smith's total costs seem more reliable.

£171 John Young, Contractor
Mayor of Annandale

his cost estimates from App noted earlier

George Mc Gredie Architect & Consulting Engineer

£75 not much movement in costs last 2 years

Labourer rates — Warren's estimates 7/6 per day
ie. a 6-day week = £5/- per week
£2/5/- = £4.50 per week

1896 Jor Book shows min salary
position of £250 ≈ £5 per week
ie. £10

Clerks & Timeskeepers £90 +
~~And 100~~ ~~£100~~
Codets £100

So labourers on about £4 per seem about right

Ammandale Sewer Aqueducts

Contract N°77 includes 2 aqueducts + tunnels.

Carter, Gummow & Co Tender £15 500
based on estimate of £14 777
but no breakdown.

Prof. Warren's estimates for total Contract

Monier system	£15 565
PWD scheme	£15 789
Warren as Contractor for PWD scheme	£17 660

Aqueducts only

Prof Warren estimates
£ 6 362 for the
common work (tunnels etc)

Monier system	£ 9 203
PWD scheme	£ 9 427
Warren as Contractor	£11 298

Contractor John Young

Monier system	£ 7 988
PWD scheme	£ 11 203

Mc Credie (Architect/Consulting Engr)
(his prices)

Monier system	£ 5 464
PWD scheme	£ 9 679

Mc Credie (PWD prices)

Monier system	£ 7 627
PWD scheme	£12 783

10601. Did the Department make the slightest effort to find out whether Mr. Gillan was connected with the firm or not? I cannot say. It was no part of my duty. J. Davis.
10602. Did you hear of anyone else making inquiry in that direction? It was no part of my duty whatever. 31 July, 1896.
10603. *Mr. Norrie.* Will you look at Mr. M'Ardle's address given in Mr. Ahearne's letter? Yes. Brisbane is given in the first instance. That is scratched out and Sydney is put in. I should imagine that seeing that Mr. M'Ardle was a Brisbane man Mr. Hickson would very properly write the minute to which Mr. Parkes has referred, not knowing anything about him.

MONDAY, 3 AUGUST, 1896.

William Henry Warren recalled, and further examined:—

10604. *His Honor.* You now have ready the report you were asked to make to the Commission as to the value of the aqueduct in the original plan of Contract 77, and also in the substituted Monier plan? Yes. I met Mr. M'Credie, Mr. Thompson, and Mr. Davis, and we agreed as to the quantities. I have a list signed by those three gentlemen giving the quantities in each case, and upon those quantities I have based an estimate. My first estimate deals with the Monier plan, and in that case the total is £15,565 6s. 5½d.; the value of the Departmental design I make £15,789 10s. 6d. That estimate was based upon the prices in the schedule less the 28½ per cent. My third estimate is based upon the same quantities, but I put in the prices myself, and I make the total £17,660. W. H. Warren.
10605. That is for the whole contract? Yes. I may mention that in each case I have added to the value of the aqueduct work £6,362 2s., in accordance with the estimates given to me by Mr. Davis, and to which Mr. Thompson and Mr. M'Credie agreed. That amount represents the quantities common to both designs, exclusive of the aqueducts. 3 Aug., 1896.
10606. Will you first give us the details of your estimate in the case of the Monier plan? Yes. My report concerning both designs is as follows:—

ESTIMATE of the total cost of the Aqueducts and Tunnels in the Contract.

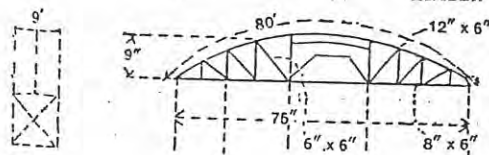
Quantity.	Description.	Rate.	£	s.	d.	£	s.	d.
1,533 cub. yds...	Material above skewbacks in Monier system	@ £3 19s. 6½d. cub. yd.	6,098	15	8			
18.2 tons	of ironwork	@ £14 per ton	254	16	0			
140	Expansion joints, at 2½ cwt. each=15.75 tons.....	@ £11 10s. per ton ..	181	2	6			
10,625	Squads of rendering, 1 to 1	@ 1s. 9½d.	951	16	5½			
158½ cub. yds.	Bluestone concrete	@ £2 10s. cub. yd. ...	396	13	4	7,486	10	7½
1,350 " ..	Sandstone concrete.....	@ £1 8s. " ..	1,890	0	0			
1,016 sq. yds.	Rendering, 2 to 1	@ 2s. 3d. sq. yd.	114	6	0			
			2,400	19	4			
	Less 28½ per cent.		684	5	6			
	Add cost of the remainder of contract in tunnels, &c.					1,716	13	10
						6,362	2	0
	Total cost of contract					£15,565	6	5½

SUMMARY.

ESTIMATED Cost of Monier Arch structure complete, per cubic yard.

Compo. and concrete in arch and carrier	£	s.	d.
Labour in do.	1	11	6
Supervision	0	17	2½
Grillage.....	0	5	0
Plant.....	0	5	6
Timber.....	0	2	5
	0	7	6½
Add 15 per cent. profit, royalty, and risk, &c., including guarantee.....	£3	9	2½
	0	10	4½
	£3	19	6½

TIMBER in Centering and Boxing.



Timber in ribs..... 280 cub. ft.

Lagging at top $80 \times 9 \times \frac{1}{2} = 1,080$ }
 Side boxing $83' \times 18' \times 1\frac{1}{2}'' = 374$ } 1,454 sup. ft. 1".
 Supporting ribs 192 cub. ft.

6 spans for small arches $2 \times 7' \times 12'' \times 2\frac{1}{2}''$ at 35 each..... 210 "
 6 spans of lagging to small arches $1\frac{1}{2}''$ 500 "
 Boxing small piers..... 750 "

Timber in sides of main carrier 1,370 "
 " ribs..... 610 "
 " lagging, 30 sup. ft., per ft. 2,475 "

Scaffolding 260 "
 Sides to small arch 160 "

732 cub. ft. + 7,517 sup. ft.

SUMMARY.

732 cub. ft., at 2s. 6d. cub. ft.	£	s.	d.
7,517 sup. ft., at 13s. per 100	91	10	0
	48	17	0
No. 4 sets of timber in str.	£140	7	0
	561	8	0

Cost $\frac{11,228}{1,533} = 7s. 6\frac{1}{2}d.$ per cub. ft. of structure.

COST

W. H.
Warren.

Aug., 1896.

Cost of labour in the Monier System.		£	s.	d.
Building 17 spans of 82 ft. 6 in. each, at £60 12s. 6d.		1,030	12	6
42 small arches, at £3 10s.		147	0	0
574 lineal feet of carrier beyond the main arches, at 5s. per foot		143	10	0
Total cost of labour		£1,321	2	6
Cost of labour per cubic yard = $\frac{£1,321 \text{ 2s. 6d.}}{1,533}$			0	17 2½
Supervision, about 5 per cent., say £375; per cubic yard = $\frac{375}{1,533}$ = about 5s.				
Cost of grills in arches and carriers, 37 tons, at £11 10s. per ton = £425 10s.; cost per yard = $\frac{8510}{1,533}$ = 5s. 6d.				
		£	s.	d.
Cost of plant, consisting of two sheds, one office, tools, barrows, &c.		150	0	0
2,000 feet of water-pipe, at 3d.		25	0	0
Cost of water, 1½d. per yard of concrete—1,533 at 1½d.		9	11	7
Cost per yard = $\frac{£184 \text{ 11s. 7d.}}{1,533}$ = 2s. 5d.		£184	11	7

ESTIMATE of the labour in one span of the Monier Arch.		£	s.	d.	£	s.	d.
To place the concrete in the arch, 1 day, 10 men at 7s. 6d., 1 man at 10s.		4	5	0			
Spandrel arches and piers, 10 men at 7s. 6d., 1 man at 10s. for 2 days		8	10	0			
To placing concrete in main carrier, 1 day, 12 men at 7s. 6d., 1 man at 10s.		5	0	0			
Making cover plates, 1 man for 4 days at 7s. 6d.		1	10	0			
						19	5 0
Timber Work—							
Making and fixing spandrel piers and arch centering and boxing—4 men at 7s. 6d., 1 man at 10s. for 4 days		8	0	0			
Making and fixing centres to main arch—12 men at 7s. 6d., 1 at 10s. (one day)		5	0	0			
Making and fixing main carrier—4 men at 7s. 6d., and 1 man at 10s. (4 days)		8	0	0			
Lagging and side boxing—12 men at 7s. 6d.		4	10	0			
Removing the above timbering, say		7	0	0			
Erecting and removing scaffolding, say		1	0	0			
						33	10 0
Ironwork—							
To make and fix the iron grid in the main arches—7 men at 7s. 6d. and 1 at 11s. 6d.		3	4	0			
small arches—5 men at 7s. 6d.		1	17	6			
Main carrier—8 men at 7s.		2	16	0			
						7	17 6
							£60 12 6

Cost of Compo. Material.

1 Cask of Cement and 12 cubic feet of Sand make 1½ cubic feet or ½ a cubic yard of Compo.—				
24 cubic feet of Sand, at 7s. 6d. a cubic yard		0	6	8
2 Casks of Cement, at 11s. 6d. each		1	3	0
Cost of Compo.		£1	9	8

Cost of Bluestone in Carrier.

10 cubic feet of Stone, 6 cubic feet of Sand, and 1 Cask of Cement make about 15 cubic feet in place				
Bluestone Toppings. Cost on Wharf, 6s. 10d. per ton, or 18.5 cubic feet to the ton—				
27 cubic feet would cost		0	10	0
Carting to Site		0	2	0
Cost of Blue Metal Toppings, per cubic yard		£0	12	0

10 cubic ft. of blue metal at 12s. per 27 cubic feet		0	4	5½
6 cubic ft. blue metal at 7s. 6d. per 27 cubic feet		0	1	8
1 cask of cement at 11s. 9d.		0	11	9
Cost of 15 cubic feet in place		0	17	10½
Cost of a cubic yard		1	12	1½

AVERAGE Cost of Compo. in Aqueducts.

383 cubic yards at £1 9s. 8d.		568	2	4
1,150 cubic yards at £1 12s. 1½d.		1,848	12	6
Average cost per cubic yard = $\frac{£2,416 \text{ 14s. 10d.}}{1,533}$ = £1 11s. 6d. nearly.		£2,416	14	10

ESTIMATE of Cost of Contract No. 77 from Departmental Design and Schedule Prices, less 28½ per cent.

1,848 cubic yards of sandstone concrete, at £1 8s.		2,587	4	0
1,054 " special bluestone concrete, at £3		3,162	0	0
1,850 " brickwork, at £2 10s.		4,647	10	0
12,190 cubic feet of freestone ashlar, at 3s. 6d.		2,133	5	0
2,682 square yards of cement facing, 1 to 1, at 2s. 6d.		335	5	0
608 " " " 2 to 1, at 2s. 3d.		68	8	0
92 cubic yards of tarred metal, at £2 8s.		220	16	0
40 scupper slates at 2s.		4	0	0
170 lineal feet of 4" scupper pipes, at 1s. 6d.		12	15	0
14 cwt. manhole covers, fixing only, at 4s.		2	16	0
56 cwt. T. irons, at 4s.		11	4	0
		13,185	3	0
Less 28½ per cent.		3,757	14	6
Add		9,427	8	6
		6,362	2	0
Total cost		£15,789	10	6

ESTIMATE of the Cost of Contract No. 77, from Departmental Designs, and Professor Warren's Estimated Prices.

	£	s.	d.
1,848 cubic yards of sandstone concrete, at £1 8s.	2,587	4	0
1,054 " special bluestone concrete, at £2 10s.	2,635	0	0
1,559 " brickwork, at £2.....	3,718	0	0
12,190 cubic feet of freestone ashlar, at 3s.	1,828	10	0
2,682 square yards of cement facing, 1 to 1, at 1s. 10d.	245	17	0
608 " " 2 to 1, at 1s. 6d.	45	12	0
92 cubic yards of tarred metal, at £2 5s.	207	0	0
40 scupper slates, at 2s.	4	0	0
170 lineal feet of 4 in. scupper pipes, at 1s. 6d.	12	15	0
14 cwt. manhole covers, fixing only, at 4s.	2	16	0
56 " T irons, fixing only, at 4s.	11	4	0

11,297 18 0

Add 6,362 2 0

Total cost £17,660 0 0

QUANTITIES agreed upon for departmental design contract No. 77.

	£	s.	d.
Sandstone concrete, 1,848 cubic yards.....	1	8	0
Special bluestone concrete, 1,054 cubic yards.....	2	10	0
Brickwork, 1,559 cubic yards.....	2	5	0
Freestone ashlar, 12,190 cubic feet	0	3	0
Cement facing, 1 to 1, 2,682 square yards.			
Cement facing, 2 to 1, 608 square yards.			
Tarred metal, 92 cubic yards.			
Scupper slabs, 40.			
4 inch cw. scupper pipes, 170 lineal feet.			
Manhole covers (fixing), 14 cwt.			
T irons (fixing), 56 cwt.			

GEORGE McCREDIE.
W. THOMPSON.
J. DAVIS.

CONTRACT No. 77.—MONIER design aqueducts—Quantities agreed to by the undersigned.

Material above skewbacks.....	1,533 cubic yards.
Sandstone concrete in piers	1,350 "
Bluestone	158½ "
Cement rendering inside and outside above skewbacks—1 to 1—½ inches thick	10,625 square yards.
" " below skewbacks—2 to 1—½ inches thick	1,016 "
140 expansion joints, cast-iron and bolts, each 2½ cwt.	18·2 ton.
Iron work exclusive of grids	

GEORGE McCREDIE.
W. THOMPSON.
J. DAVIS.

21/7/96.

CONTRACT No. 77.—ANNANDALE.—QUANTITIES common to Monier and Departmental Designs in tunnels, roadways, &c., &c., not including aqueducts (30·02 chains).

Item.	Description of Work.	Unit.	Quantities.	Rate.	Amount.
					£ s. d.
1	Excavation.....	Cubic yards	4,243	2/-	424 6 0
2	"	"	140	7/-	49 0 0
3	"	"	1,160	6/-	348 0 0
4	"	"	90	65/-	308 15 0
5	"	"	100	60/-	300 0 0
6	"	"	1,000	57/6	2,875 0 0
7	"	"	70	6/-	21 0 0
8	"	"	4	22/6	4 10 0
9	"	"	70	20/-	70 0 0
10	"	"	2	30/-	3 0 0
11	Filling.....	"	2,300	1/-	115 0 0
13	Sandstone ballast	"	740	4/-	148 0 0
14	Bluestone metal	"	370	12/-	222 0 0
15	" screenings	"	180	5/-	45 0 0
16	Subducts.....	Lineal yards	50	1/6	3 15 0
17	Timber	Cubic feet.	300	1/8	25 0 0
18	Piling	Lineal feet..	960	4/-	192 0 0
27	Curbing	"	650	2/6	81 5 0
26	Ashlar	cubic feet...	130	3/-	19 10 0
28	Gully covers	each	4	18/6	3 14 0
30	Bluestone pitchers	square yard	8	12/6	5 0 0
31	Freestone	"	320	8/-	128 0 0
32	Fencing	rod.....	50	18/-	45 0 0
33	"	"	100	8/-	40 0 0
34	21-inch pipes	lineal yard..	120	33/-	198 0 0
35	12-inch "	"	20	6/9	6 15 0
36	9-inch "	"	15	5/-	3 15 0
39	Surplus material	cubic yard...	4,580	1/1	248 1 8
40	Fixing ironwork	cwt.	125	4/-	25 0 0
41	Flap traps	each	10	25/-	12 10 0
19	Sandstone concrete	cubic yard...	322	28/-	450 16 0
20	Bluestone	"	707	50/-	1,767 10 0
22	Brickwork	"	156	50/-	390 0 0
23	Rendering 1 to 2	square yard	2,835	2/3	318 18 9
					8,898 1 5
	Deduct 28½ per cent.				2,535 19 5
					6,362 2 0

F. M.
Gummow.

28 Sept., 1896.

19656. When you came across, did you consult any officer of the department as to the prices? No.
19657. Had you any communication at all with Mr. Hickson? No.
19658. You never asked him whether you could put in the Monier tender or not? No.
19659. You never had any words with him in any way on that subject? No.
19660. Nor with any officer of the department apart from Mr. Baltzer? No.
19661. What did Mr. Carter say to you when you came across, and when he asked you to make up the tenders? I do not recollect what he said particularly. I remember going across to the North Shore office, and Mr. Snodgrass had there the plan and also his estimate. They asked me to look through it and see what I thought of it. That is what it amounted to. I went through the estimate and criticised it.
19662. Do you know where the estimate is now? Yes.
19663. Have you the original one? Yes.
19664. Can you produce it? Yes. It is rather a ragged looking document, but it is the one which was made up at the time.
19665. In whose handwriting is it? A boy named Norman Burkett copied it for Mr. Snodgrass. It is the estimate which Mr. Snodgrass made out.
19666. *Mr. Parkes.* The total, I see, is £14,677 10s. Yes. There is an error of £100 in the addition. It should be £14,777 10s.
19667. *His Honor.* You say you went through the estimate;—to what conclusion did you arrive? We differed on some points. For instance, in the quantities attached to the first two items. You will see that Mr. Snodgrass's quantity for the tunnel in lineal yards was 750. On the margin you will see that I have written in pencil 723. Then, in regard to item No. 2—shafts—Mr. Snodgrass estimated 100 lineal feet, and I had written in the margin 49. The entire estimate is as follows:—

CONTRACT No. 77.—Estimate of Cost on Monier System.

	£	s.	d.		£	s.	d.
Tunnel, lineal yards	750	85/-	3,187 10 0	Gully covers	4	20/-	4 0 0
Shafts, lineal feet	100	35/-	175 0 0	Blue pitchers	8	30/-	12 0 0
Monier, mortar	1,070	70/-	3,745 0 0	Sandstone pitchers	320	6/-	96 0 0
Sandstone concrete	1,800	23/-	2,070 0 0	Two-rail fence	50	20/-	50 0 0
Iron, $\frac{3}{4}$ and $\frac{1}{2}$, ton	44	10/-	440 0 0	Two-rail and wire	100	8/-	40 0 0
Tie-bars	2	15/-	30 0 0	24-in. pipes	120	30/-	180 0 0
Channel iron	20	15/-	300 0 0	12-in. "	20	6/-	6 0 0
Cast-iron	12	10/-	120 0 0	9-in. "	15	5/-	3 15 0
Rendering	12,000	2/-	1,200 0 0	Surplus	4,000	-/6	100 0 0
Piles	1,200	4/-	240 0 0	Plant			488 5 0
Open cut—soft	4,000	1/9	350 0 0	Management			750 0 0
" rock	1,200	4/-	240 0 0	Smith			200 0 0
Filling	2,000	-/6	50 0 0	Sundries			300 0 0
Sandstone ballast	700	3/-	105 0 0				
Blue-metal	350	10/-	175 0 0	Total			£14,677 10 0
Screenings	180	2/6	22 10 0	Price sent in			£15,500 0 0
Sandstone ashlar	130	2/6	16 5 0				
Kerbing and guttering	650	2/6	81 5 0				

19668. *His Honor.* I understand that you made your own calculations from the data upon which Mr. Snodgrass had been working? Yes.
19669. He is an engineer, I understand? I do not think he has been through any particular course, but he is a practical man, who has been with contractors for a long time. He has been through the drawing office, and he has had to go through a course of mathematics, but he has never passed any particular examination. He has been through a practical course of engineering with good engineers.
19670. Under good practical engineers? Yes. I believe he gained his experience principally upon railways in New Zealand, under a very large English firm—Brassey and Betts—who had work to do there. He went through the mill, you might say, including practical working in the office, and also outside. He can do instrument work, and everything of that kind. He is thoroughly capable. I do not think he could go into the higher mathematics, but that would be about the only thing he has not studied. He is capable as regards all general mathematical questions.
19671. *Mr. Parkes.* I see that in Mr. Snodgrass's estimate sandstone concrete is put down at 23s. a yard—is that a fair value? I should say so.
19672. Shaft excavation is put down at 35s. a lineal foot? That is made up in a peculiar way. It includes the concrete as well.
19673. The tunnel, I see, is put down at 85s. per lineal yard;—would that include the brickwork? The brickwork and the concrete, but not the rendering.
19674. You have put down rendering at what? At 2s. a yard, the quantity being 12,000 yards.
19675. You have not your original estimate upon the departmental scheme for Contract 77? No; I have been looking for that, but I cannot find it.
19676. You have put down cast-iron at £10 a ton, and $\frac{3}{4}$ and $\frac{1}{2}$ in. iron-bars are also put down at £10 a ton? Yes.
19677. I suppose that was the market value at the time? Yes; I think you may take that as the fair market value.
19678. Had you any piling under the foundations of your piers? Yes; 1,300 odd feet. The Government specified 900, I believe. Mr. Snodgrass and I agreed in the main, though not in the details. Mr. Snodgrass's prices were a little too low, but then he had his quantities a little too high, so that the one balanced the other. Finally, when we made up our tender for the Monier design, we put it at £15,500, so as to be a little below our estimated cost of the Government design.
19679. You bought the timber for the job solely from Guy & Co.? Yes.
19680. If Guy & Co. shows for the two works, 77 and 118, a total of £568 5s. 2d., that would be the total amount paid? If that is what it shows.
19681. If Guy's accounts contain a great deal of timber which would be used for keeping back the earth in Contract 118, that would considerably reduce the total of £568? I do not think any timber was used on Contract 118 for keeping back earth.
19682. Did you ever see the work? Yes.

Appendix No. 15.

CONTRACT No. 77—"MONIER SYSTEM"—JUNE 4TH, 1896.

Quantities and estimated cost Johnstone's and White's Creek Aqueducts. Above footings. Total length of both Aqueducts, 30½ chains.

	£	s.	d.
Sandstone Concrete—			
852 cubic yards in piers=9 full piers, containing 2,556 cubic feet, each,—21s.	894	12	0
Blue-metal Concrete—			
682 cubic yards in piers, in spandrels of arches and base bottom of channel,—40s.	1,364	0	0
Compo.—			
In all arches.....	11,260	cubic feet	
Bottom channel, including plinths	2,896	"	
1,084 cubic yards, top, including cornice and coping,	2,558	"	
Bottom angle corners	5,340	"	
Sides of channel	7,216	"	
	29,270	cubic feet,—30s.	1,626 0 0
Ironwork—			
16,776 lb. in ¼" dia. side and top iron bars			
33,218 " in ½" " top cross-bars and side vertical bars			
4,880 " in ¼" " cross-bars in arches			
11,200 " in ¾" " longitudinal bars in arches=29 tons 9 cwt. 3 qrs. 22 lb (say) 30 tons,—£10	300	0	0
34,100 " in 1" " Channel-plates drilled for ties.....			
1,788 " in ½" " top tie-rods with heads, threads, and nuts.....			
2,012 " in ¾" " bottom tie-rods	260	0	0
4,000 " bolts and nuts=19 tons 12 cwt. 16 lb. (say) 20 tons,—£13	120	0	0
12 tons cast-iron plates,—£10	900	0	0
12,000 sup. yds. cement rendering,—1s. 6d.			
	£5,464	12	0
Cost per foot run.....	2	13	8
Cost per yard cube	2	1	9

Particulars showing how values have been estimated.

Sandstone Concrete—			
5 yards sandstone,—2s. 6d.	0	12	6
2 " crushed sandstone (sand),—2s. 6d.	0	5	0
1 " = 6 casks of cement, per cask,—9s. 6d.	2	17	0
which makes 5 yards cube of concrete	3	14	6
= 14s. 11d. per yard for material, 6s. 1d. per yard for labour, timbering, &c.	1	1	0
Blue-metal Concrete—			
7 yards blue-metal,—12s.	4	4	0
3 " crushed sandstone (sand),—2s. 6d.	0	7	6
2 " cement = 12 casks, per cask,—9s. 6d.	5	14	0
which makes 7 yards cube of concrete	10	5	6
= £1 9s. 4d. per yard material, 10s. 8d. per yard labour, boarding, &c.	2	0	0
Compo.—			
3 yards sand,—2s. 6d.	0	7	6
1 yard cement= 6 casks, per cask,—9s. 6d.	2	17	0
which makes 3 yards cube of compo.	3	4	6
= £1 1s. 6d. per yard material, 8s. 6d. per yard labour, boarding, &c.	1	10	0

CONTRACT No. 77—DEPARTMENTAL DESIGN—JUNE 5TH, 1896.

Quantities and estimated cost, Johnstone's and White's Creek Aqueducts. Above footings.

	£	s.	d.
Brickwork—			
1,760 cubic yards double-pressed bricks,—40s.	3,520	0	0
Special Bluestone Concrete—			
1,282 cubic yards. Round sewer,—40s.	2,564	0	0
Sandstone Concrete—			
1,362 cubic yards piers and haunches of arches behind brick,—21s.	1,430	2	0
11,774 cubic feet Pyrmont ashlar,—3s.	1,766	0	0
95 cubic yards tarred metal decking,—40s.	190	0	0
2,662 superficial yards cement rendering,—1s. 6d.	199	13	0
130 cubic yards sand-filling,—1s.	6	10	0
40 No. slate covers,—1s. 6d.	3	0	0
	9,679	7	0
Cost per foot run.....	4	16	2

CONTRACT No. 77—"MONIER SYSTEM"—JUNE 8TH, 1896.

Quantities and estimated cost, Johnstone's and White's Creek Aqueducts. Above footings. Departmental prices as per Schedule.

	£	s.	d.
852 cubic yards sandstone concrete,—23s.	1,192	16	0
682 " blue-metal " 60s.	2,046	0	0
1,084 " compo. 40s.	2,168	0	0
30 tons ironwork (fixed),—£10	300	0	0
20 " channel-plates; drilled tie-rods, bolts, &c.,—£15	300	0	0
12 " cast-iron plates,—£10	120	0	0
12,000 superficial yards cement rendering,—2s. 6d.	1,500	0	0
	7,626	16	0
Cost per foot run nearly.....	3	15	9½

CONTRACT

CONTRACT No. 77—DEPARTMENTAL DESIGN—JUNE 8TH, 1896.

Quantities and estimated cost, Johnstone's and White's Creek Aqueducts. Above footings. Departmental prices as per Schedule.

	£	s.	d.
1,760 cubic yards brickwork,—50s.	4,400	0	0
1,282 " special bluestone concrete,—60s.	3,846	0	0
1,362 " sandstone concrete,—28s.	1,906	0	0
11,774 cubic feet Pymont ashlar,—3s. 6d.	2,060	9	0
95 cubic yards tarred metal decking,—18s.	228	0	0
2,662 superficial yards cement rendering,—2s. 6d.	332	15	0
130 cubic yards sand filling,—1s.	6	10	0
40 No. slate covers,—2s.	4	0	0
Total	£12,783	14	0

Price per foot run, 2,013 feet, £6 7s.

CONTRACT No. 112.—18TH JUNE, 1896. FOURTH DIVISION WESTERN OUTFALL SEWER.

Total length, 2,320 ft. 1 in., made up in—40 arches, 50 feet span each, 2,000 feet; 38 piers, 8 feet wide each, 304 feet; 4 piers, 4 feet wide each, 16 feet; total, 2,320 ft. 1 in.

Aqueduct only, without approaches or piers, for bridge in centre.

Sandstone Concrete—			
3,108 cubic yards, in piers and spandrels of arches and footings of piers,—22s.	3,418	16	0
Bluestone Concrete (special)—			
1,613 cubic yards, in channel,—49s.	4,025	7	0
Bluestone Concrete (ordinary)—			
1,388 cubic yards, in arches and skewbacks of piers,—40s.	2,776	0	0
Excavations—			
1,230 cubic yards, for footings and foundations,—2s. 6d.	153	15	0
Cement Rendering—			
4,202 superficial yards, inside, 1 of cement to 1 of sand,—2s.	420	4	0
8,031 " external faces, 1 of cement to 2 of sand,—1s. 6d.	602	6	6
Ironwork—			
56 tons 13 cwt. 1 qr. 24 lb. (say) 57 tons, £13	741	0	0
459 superficial yards—Val de Travers and bitumen and cork dampcourse; mastic jointing, &c.,—10s.	229	19	0
Total	£12,367	7	6

Cost per foot run, £5 6s. 7½d.

No. 77.—Cost of Departmental Design, Contract No. 77, including foundations, per foot run	5	1	3
Mr. M'Credie's prices:—Total cost, £10,192 7s.			
As compared with office prices, departmental plan, per foot run	5	19	3
£12,000.			
No. 77.—Cost of Monier Design, Contract No. 77, including foundations, per foot run	3	2	3½
Mr. M'Credie's prices:—Total cost, £6,168 2s.			
No. 101.—Cost of Contract No. 101, Western Outfall Sewer, constructed similar to design, but for one-barrel drain instead of three, as shown, at per foot run	4	15	4½
At departmental rates, £6 10s. 8d.			

Comparative Areas of Sections—

No. 112.—When full, 41.22 superficial feet; when three-quarter full, 29.48 superficial feet.

No. 77.—Departmental Design—

White's Creek, when full, 13.0 superficial feet; when three-quarter full 14.0 " " "

Johnstone's Creek, " " "

Monier Design—

White's Creek, when full, 11.56 superficial feet; when three-quarter full, 8.12 superficial feet.

Johnstone's Creek, " 13.5 " " " 9.57 "

No. 101.—The barrel drain, when full, 28.27 superficial feet.

GEO. MCCREDIE.

Appendix No. 16.

DEPARTMENT OF PUBLIC WORKS.—METROPOLITAN SEWERAGE CONSTRUCTION.—TENDER FORM.—BALMAIN AND LEICHHARDT EXTENSION, 3RD DIVISION, NORTHERN MAIN SEWER.

Contract No. 117.

In pursuance of an advertisement in the *Government Gazette* (I or we), the undersigned, do hereby tender to provide the material and perform the various works required in and about the full and proper construction, erection, and completion of the Balmain and Leichhardt Extension, 3rd Division of the Northern Main Sewer, agreeably to the Plan, Specification, Schedule to Specification, Special Conditions, and General Conditions, which have been inspected by (me or us), at _____ per cent. the prices affixed to each item, in the Schedule of Prices annexed hereto, and to complete the same within ten months from the date of the acceptance of this Tender; and (I or we) do hereby agree that any additions to or deductions from the said works shall be paid or allowed for, as the case may be, at and after the rate quoted above, or if not in Schedule, at a price to be agreed upon at the time, and (I or we) hereby undertake that (I or we) will, within fourteen days from the date of the notification of the acceptance of the said Tender, execute and deliver to the Minister for Public Works a valid legal Contract with Her Majesty the Queen, embodying the terms and conditions above mentioned, and to provide the security required by clause 29 of the said General Conditions; and (I or we) enclose herewith (our or my) cheque for the sum of £77 as a preliminary deposit; and (I or we) agree that such sum shall be absolutely forfeited if (I or we) at any time within thirty days after the said Tender is opened withdraw the same, or if in the event of this Tender being accepted (I or we) fail to complete the above-mentioned Contract document within fourteen days thereafter; and further, that this Tender is made subject to the Conditions contained in the Tender Board Regulations, printed on the back hereof, and by which (I or we) agree to be bound.

Dated this _____ day of _____ 189 _____

This is the Tender marked " _____ " referred to in _____ annexed Agreement with Her Majesty the Queen, dated the _____ day of _____ A.D. 189 _____

Witness—

TENDER BOARD REGULATIONS.

No tender shall be received after 11.30 a.m. on the day named for the receipt of such Tender, unless there are circumstances which, in the opinion of the Members of the Board then sitting, render it desirable to do so.

It shall be the duty of the President, Vice-President, or the senior member present, as the case may be, as soon as the Tenders shall have been opened and the necessary particulars ascertained, to publicly announce the number of Tenders received for each work and the name of the lowest Tenderer; but no Tender shall be accepted until the Head of the Branch, under whose directions the work is to be carried out, has reported upon the whole of the Tenders received. The

it would repay any engineer to replace them with new ones, as a very small leak in the gland leather kept the attendant constantly at the glycerine pumps so that the gland box will be kept full, and so keep the CO_2 from escaping. Now, if we take into consideration a machine with a stroke of eighteen inches (18in.) working at 90 revolutions per minute—that is 16,200ft per hour, 388,800ft per day of 24 hours, 2,332,800ft per week of six days. And bring these figures to miles for four weeks running we find that the Compressor piston rod has travelled the great distance of 1767 miles through two leathers, these having to resist a pressure of, at least, 1300 lbs. per square inch at the same time, and he thought that many would agree with him that it is hardly to be expected for a leather to stand so long. There was one point he would like to touch upon and that was the suction valves in the compressors. The seats of these valves project into the cylinder of the compressor with a perforated guide for valve, and the piston head working with only $1/32$ nd of an inch clearance. The slightest twist in the rod, or looseness of brass in connecting rod, causes seat to be struck, and so fastens the valve down and prevents it from working.

9TH SEPTEMBER, 1897.

THE MONIER SYSTEM AND ITS USES.

By MR. W. BALTZER.

In response to the invitation of the Council to supplement a paper on the Monier System, read by Mr. Cutler last year, the author from the many sources at his command, compiled a paper which he hopes will prove of interest, knowing that this system has been very prominently discussed during the last twelve months. To make the paper more interesting and easy to follow, the author has refrained from entering into any abstruse calculations or intricate theories, contenting himself with touching upon the general principles of the system, and bringing into notice the opinions and experience of none but leading engineers and scientists, together with the results of authenticated tests.

MONIER SYSTEM.

The component parts of constructions built on the Monier System referred to in this paper are:—

1. Round iron bars, and
2. Cement mixtures which are combined to form one mass.

The principle of this combination is to augment the tensile strength of the cement mixtures in those sectional areas, which are subject to tension by the judicious insertion of iron, in order to utilise to the fullest extent the great compressive strength of the former, and also to add elasticity to the construction.

It is well known that the tensile strength of cement mixtures is only from 1/10 to 1/20 of its compressive strength, consequently that part of the sectional area subject to tension must either be disproportionately larger than the part subject to compression, or if constructed of rectangular cross section, it must be designed entirely with regard to the tensile strength of the cement mixtures only, thus sacrificing a very large quantity of material in that area, which is subject to compression. To avoid this, the principle of the Monier System can be adopted, and thus the great compressive strength of the cement mixtures can be rationally utilised.

The principle of the Monier System, viz., the embedding of the iron bars in cement mixtures, is mainly dependent on three salient points:—

1. The adhesion of cement mortar to the Iron.
2. The action of the two materials under varying changes of temperature.
3. The impossibility of oxidation of iron embedded cement mixtures, and consequent non-destruction or loosening of the iron.

With regard to these points, no greater authority than the Late Professor Bauschinger, of the Technical High School, Munich, need be referred to, he being one of the leading authorities of the day on Building Materials, and recognised as such in the best English Engineering works on the subject.

In a report dated 20th December, 1887, he makes the following statements:—

1. "The adhesion of the two materials, cement and iron, is from 570 to 670lbs per square inch.
2. "Regarding the action of the two materials under varying changes of temperature, my tests to determine the co-efficient of expansion of cement mortar carried out in 1876, as well as those I carried out recently, showed that the co-efficient expansion of cement mortar cannot under all circumstances be accepted as equal to that of iron, but

it may be taken for granted, judging from the action of the tested Monier Objects, that no separation of the iron and cement Mortar, prejudicial to its strength, takes place, even under high and rapid changes of temperature, for the reason that the elasticity and great adhesion of the materials equalise any variations that may arise in the co-efficient of expansion and contraction between cement mortar and iron."

"Relative to the impossibility of oxidation of the iron in the cement, I may state that as the result of adhesion tests made with Monier objects three months old and exposed to all weathers, that the irons cut out of the cement mortar were perfectly clean and free from oxidation, whereas the exposed ends were very much rusted."

In his second report, dated 27th July, 1892, the Professor deals with the examination of fragments of Monier objects made in 1887, and states:—

"These objects had been exposed to all weathers for five years, some being nearly always covered with water (in a sewer inlet), frequently intermixed with urine. From the tests made I am satisfied that cement mortar in Monier objects adheres strongly to the iron insertions, and that the iron remains perfectly free from rust in spite of the influence of all weathers, and frequent changes of temperature."

These extracts from the reports of one of the most eminent scientists in the researches of building materials should be sufficient to set at rest all doubts concerning these three salient points of the principles of the Monier System. And taking these into consideration, it is evident that a combination of iron and cement mortar, as carried out in this principle, must form a homogeneous and elastic body, expanding and contracting conjointly—subject to the co-efficients of elasticity of materials—and not less durable than cement mortar itself under climatic changes.

The principal advantages of this system are:—

1. Strength, combined with elasticity.

2. Fire resistance.
3. Lightness in construction and saving in space.
4. Quickness and simplicity of erection.
- v. Cheapness.

STRENGTH.

Regarding the Strength of the Monier Structures, the results of a few of the principal tests will be sufficient to allow a comparison to be made with structures of other materials.

The most important tests of arches were those carried out at Matzleindorf, in 1889 and 1890, and at Purkersdorf in 1892.

The Matzleindorf test was instituted by the Imperial South Railway Company in order to satisfy the demands of the Government regarding the suitability, or otherwise, of the Monier system for overhead bridges.

The Railway Company was obliged, through the alteration of its rolling stock, to increase the height of its existing overhead bridges on the Liesing to Felixdorf line and after careful consideration and tests, they decided that the Monier System was the most suitable to allow of this being accomplished without raising the existing road levels, and at the same time the cheapest, as iron structures involved a very large expenditure.

An arch 32ft. 8in. span, 13 feet wide, 6 inch thick at the crown, and 8 inches at the abutment was erected, and tested exhaustively, first with rolling stock, and then with a one sided load of iron rails, with most satisfactory results, the arch finally collapsing with 17cwt. 3qrs. per square foot owing to the abutments spreading.

The most exhaustive and scientific tests of arches on record is the one made at Purkersdorf, in 1892. It was carried out by the Austrian Engineers' and Architects' Association to obtain the fullest information in order to prove and perfect the theory of the arch construction.

Four test arches were built:—Rubble, Brick, Concrete, and Monier. Each arch had a span of 75 feet 5 inches, versed sine of 15 feet 1 inch and a width of 6 feet 6½ inches.

These arches were calculated to carry with safety an equally distributed one sided load of 306lbs. per square foot horizontal surface. The tests were made with a one-sided load extending to the crown, the load being placed on an iron staging which transmitted the pressure by means of six supports on to level and equally spaced footings built on the Arch.

The first hair cracks occurred in the Rubble under a load of 56.5 tons, in the brick arch under 42.2 tons, in the concrete arch under 63.3 tons, and in the Monier arch under 78.5 tons.

The Rubble arch collapsed under 74 tons.

The Brick arch collapsed under 67.5 tons.

The Concrete arch collapsed under 83.3 tons.

And the Monier arch collapsed under 146.1 tons.

Making a comparison of these figures it will be seen that the breaking load of these arches compared with the Monier Arch (the latter taken as 100) is:—

For Rubble	51
For brick	46
For Concrete	57
And for Monier	100

And comparing the tensile strengths of the materials used it is found that the tensile strains which caused the first hair-cracks in the different sectional areas varied:—

In the Rubble arch from 95 to 133lbs. per sq. in.
In the Brick arch from 58 to 109lbs. per sq. in.
In the Concrete arch from 205 to 369lbs. per sq. in.
In the Monier arch from 522 to 712lbs. per sq. in.

thus demonstrating the great tensile strength and homogeneity of the Monier material.

A test of two arches was made at Forest Lodge on the 14th November, 1895, in the presence of Mr. C. W. Darley, Engineer-in-Chief for Public Works. The arches were built

on the 18th September, 1895, and were, therefore, only two months old when tested.

The span of the arches was 20 feet 6 inches; width 4 feet; versed sine 1 foot 10 inches; thickness at crown, 3 inches; and at abutment, 5 inches.

Gauges were fixed on to the faces of the arches, and constructed to register both vertical and horizontal deflections.

The loading consisted of Pig-iron, bags of cement, and sand carefully weighed and distributed over the arches, amounting to 34.5 tons on the one, and 35 tons on the other, or 910lbs. and 922lbs. respectively per square foot.

This test was deemed ample and satisfactory for strength. As no cracks had occurred, and further loading would probably have endangered the men's lives, on account of the height of the load. Further tests were then made for electricity, which is referred to later on.

Numerous other tests were made by Professor Bauschinger in 1887, some of which are detailed as follows:—

(1) A plate $1\frac{1}{2}$ inch thick, 3.28 feet wide was fixed at ends supported on piers 3.28 feet apart, and tested with 282lbs per square foot equally distributed, when fine hair cracks appeared on top of the plates near the supports. With 538lbs per square foot equally distributed, two fine hair cracks appeared in the centre on the lower side of the plate, and it was then loaded with 649lbs per square foot without further damage.

It was then unloaded, and a concentrated load of 366lbs was applied at the centre, crushing the plate, which, however, did not collapse as it supported the load for several days.

(2) A plate $2\frac{1}{2}$ inch thick on supports 6 feet 6 inch apart, broke under a load of 501lbs per square foot, but did not collapse, the load being still supported.

(3) Another plate 4 inches thick on supports 9 feet 8 inches apart was loaded with 823lbs. per sq. ft., the plate broke, but did not collapse, the load being still supported.

In February, 1886, the Police Authorities at Berlin tested a pipe similar to the pipe exhibited by Carter, Gummow & Co., at the recent Engineering and Electrical Exhibition, Sydney. The pipe 3 feet 3 inch diameter, $1\frac{1}{2}$ inch thick was loaded with 5.1 tons which caused the pipe to crack at the outside surface of the horizontal diameter, but the cracks did not extend through the thickness of the pipe, so that it would still remain watertight.

An oval pipe 3 feet 2 inches by 2 feet 4 inches resting on supports 3 feet 8 inches apart was tested, and subject to two concentrated loads 3 inches apart equally spaced between supports. With a total load of 3.2 tons, a crack extending along the entire length appeared near the bottom, on the outside only.

A pipe 6 feet 6 inches diameter and 4 inches thick with a load of 23.5 cwt per square foot, showed hair cracks on the inside of the pipe at crown and invert, the load was increased to 38.7 cwt per square foot without seriously damaging the pipe, as the cracks did not extend through its entire thickness, but reached only to the middle from either side.

A Monier Wall, self supporting, 13.12 feet, between supports 8 feet $2\frac{1}{2}$ inches high, $2\frac{1}{2}$ inches thick was tested by Professor Bauschinger in 1887, and with 7 tons showed no signs of buckling.

A Monier Wall 11 feet 6 inches high, and $1\frac{1}{2}$ inches thick, on supports 6 inches apart, was tested in February 1886, by the Berlin Police authorities, a load of 10 tons did not cause a vertical deflection or buckling, although holes had been cut in to test its stability.

ELASTICITY.

From tests made in 1886-7 it was definitely agreed that the theory of elasticity was applicable to Monier constructions, the correctness of which was later on proved by tests made at Purkersdorf in 1892.

The scientific observations made at these later tests comprised:—

- (1) The vertical and horizontal deflection of points on the centre line of the arch and the abutments in relation to fixed points outside.
- (2) The measurements of the alteration of the angle of cross section of the arch.
- (3) The recording of cracks or any other developments.

The object of these tests was not only to find the most exact calculations for the static stresses, but also to discover from the test data, the manner in which the inner stresses distribute themselves over the Concrete and iron insertions respectively, and to what extent the latter assist.

The examination was based on the method of Castigliano's "Theory of Elastic Systems," which is independent of every approximate assumptions of form and cross-section, in order to attain the most exact result.

The recorded deformations and cracks were in perfect accord with the calculations, and it must be specially noted that the appearance of the cracks taking place near the unloaded abutment, next at the so-called dangerous points, and then lastly near the loaded abutment, was in accord for the calculations for the theory of elastic arches, and proved the homogeneity of the material and the fact that this theory can be correctly applied to arches without abutment joints on the Monier system.

The tensile strain at the different cross-sections of the arch when the first hair-cracks appeared were from 522 to 712 lbs per square inch, and as the tensile strength of the concrete alone was only 284 lbs., it is clear that the iron insertions embedded and forming with the concrete a homogeneous mass increased the strength of the body to double that of the concrete thus showing what an important factor the iron insertions play in the Arch.

The co-efficient of elasticity of the body, as derived from the deflections noted, showed a gradual decrease under the increased loading, but it was found that this decrease was of no consequence, as the arch still acted as an elastic body on account of the iron insertions being still perfectly elastic.

The ratio of the distribution of the stresses through the Concrete and iron, under an assumption of a constant co-efficient of elasticity for the iron insertions, varied from 1 to 15 to 1 to 70, as the load was increased to 78.5 tons at which stage hair cracks appeared, showing that the elastic limit of the homogeneous material had been exceeded.

The tensile strain on the iron at that stage varied from 8.2, 5.1, and 5.3 tons, showing that the iron was still perfectly elastic, though the elastic limit of the arch had been overcome, thus showing that a very marked increase in the safety of such an arch, is obtainable, by the insertion of iron rods when compared with an arch of concrete alone, so that greater stresses can be allowed on the sectional area of a Monier construction than would be admissible in stone, brick, or concrete.

On account of the great elasticity of this material, the many and considerable impacts caused by rolling loads on bridges, are taken up and distributed throughout the construction, instead of being heaped up at the point of impact as is the case in less elastic bodies; so that the live force of the impact exhausts itself without any injurious effect.

The great number of bridges in use substantiate this, as well as the fact that Monier arches tested as coverings for bomb proof chambers have given such excellent results that it is extensively used for that purpose in the new fortifications of Germany. A bridge at Ingolstadt, erected 1891, is a striking example of the suitability of the system to Bridge Construction. The roadway lies direct on the Monier plates, which are only $2\frac{3}{4}$ inches thick, and the traffic is a very

heavy one, the bridge being frequently crossed by marching regiments and heavy artillery.

The system has also been applied to Railway Bridges, Railway Culverts, etc., with the greatest success. Among these may be mentioned the railway bridge, Jever to Carolinensiel, 13 feet span; bridge to Neustadt, Western Prussia, 42 feet span; four bridges at Hamburg, 42.6 ft. span, besides a great number of culverts in Europe and South America.

One of the tests of the arches erected at Forest Lodge had for its object the elasticity of the same. Earth was placed on to each arch and levelled to 1 foot above the extrados of the crown. Then fifty able-bodied men stood on top, and observations were taken of the gauges whilst the man kept time jumping together, and it was found that 1/20th inch was the greatest deflection at the centre.

As already mentioned under the heading of strength, one of these arches was loaded with 35 tons. The gauges fixed at the crown of the arch showed a deflection of 13/20 inch, which disappeared gradually whilst unloading, and when the load was altogether removed the arch had returned almost to its normal condition without leaving an appreciable permanent set or cracks in any part.

FIRE RESISTANCE.

The question of fire resistance is one of the most vital points which determine the value of a material to be used in building constructions, and in dealing with this subject special stress must be laid on the fact that no building material can be said to be absolutely fireproof; but only fire resisting, such resistance being of incalculable benefit in checking the spread of a conflagration until preventive means arrive.

The opinion of the authorities, in whose hands rest the supervision and responsibility of the erection of buildings, the experience gained from large fires, and the result of extensive tests, should convince the most sceptical of the great fire resisting qualities of the "Monier" material.

In 1886, the Police Authorities of Berlin, after a most exhaustive test with this material, issued a proclamation that the Monier system could be used for the ceilings and walls in the erection of perfectly fireproof constructions and that no objection would be taken to its applications for the mantlings of iron columns without an isolating layer of air.

A great fire which occurred in 1889 at the Spirit Factory of Heinrich Helbing, at Wansbeck, near Hamburg, fully justified the issue of the proclamation.

The floors and ceilings of this factory were built of Monier plates resting upon iron Girders, throughout every story; the plates having a thickness of 1 3/4 inches to 2 3/4 inches according to the load they had to sustain. The Girders were not protected in any way, the floors simply resting upon the upper flanges.

The outbreak of the fire occurred in the roof, which quickly burnt down to the garret floor. This floor effectually checked the progress of the fire, preventing it from reaching the lower floors, in which were stored tanks of spirits, leaving sufficient time for the removal of the spirits to another building.

The City Architect in his report upon this fire, stated that the Monier floors successfully resisted the heat, remaining intact and prevented not only the flames from spreading, but also the water which poured into the building, from flooding the lower stories.

In 1889, the Association of the Private Insurance Companies of Germany placed at the disposal of the Committee of the Exhibition for the prevention of accidents in Berlin, the sum of £500 to be expended in prizes for improvements against risk of fires; and tests were accordingly instituted in order to discover the best system of building construction to withstand conflagrations.

In order to assist in this matter, the City of Berlin presented to the Committee a condemned building in which to conduct their experiments.

The interior of the building was demolished, and the various competing systems were erected therein in accordance with the usual design of every-day buildings.

The Monier structures consisted of an arched floor 13ft. span and $3\frac{1}{2}$ inch thickness, and plates, resting in some instances on the upper flanges and in other cases on the lower flanges of iron girders; and a staircase constructed with Monier side walls in the shape of rising arches supporting a plate 3ft. wide and 2 inches thick on which the steps were concreted.

All the exposed iron parts of the ceiling construction, the sides, upper and flanges of girders were protected by Monier mantles.

The Constructions were tested on the 11th February, 1893, by being exposed to a great heat for one hour, the temperature for the ceilings reached 1800 degrees Fahr., and for the Staircase 2000 degrees Fahr. Water was then freely poured into the building until the flames were extinguished, and an examination of the various structures made.

The Monier ceilings were found to be practically uninjured excepting that the rendering had peeled off in some places, but their stability had not been affected in the slightest degree as a load of 534 lbs per sq. ft. which was then placed upon them did not cause any deflection or cracks.

The edges of the large arch openings in the side walls of the Monier Staircase showed the iron netting partly exposed in several places, caused by the peeling off of the cement covering.

This was probably due to the rapid cooling of the material owing to the action of the water with which the building had been deluged.

The staircase otherwise remained intact. On being loaded up to 470 lbs per sq. ft. it showed no signs of injury.

After exhaustively examining the various systems tested, the Committee decided that the Monier system was perfectly fire-resisting, and it was accordingly awarded First Prize.

LIGHTNESS AND SAVING IN SPACE.

The lightness of the Monier Constructions, and consequent saving in space compared with other structures can plainly be seen by reference to photos exhibited or to the illustration which appeared in this Journal on the 24th July last.

The new Catholic Church at Munich has a ceiling of Semi-circular design consisting of a Monier arch 52 feet 2 inches span, and $2\frac{1}{2}$ inches thickness.

The casing round the High pressure Reservoir at Emerich, built in 1888, has walls of only $1\frac{1}{4}$ inches thickness.

The walls, roof, reservoir, and chimney of the Municipal Baths at Munich are constructed on the Monier System.

The Cupola over the Mausoleum of the Emperor Frederick at Potsdam, consists of an outer and inner mantle each of only $3\frac{3}{8}$ inches thickness.

The Reservoir at Drossen represents a type generally used at small stations on the Continent. The Reservoir is $3\frac{1}{4}$ inches thick, and the encasing 2 inches.

The Reservoir tower at the Municipal Gasworks, Charlottenburg, is constructed with Monier Floors, roof and reservoirs. The reservoirs up to 23 feet diameter have walls of only $2\frac{1}{4}$ inches thickness.

Types of floors consisting both of plates and arches, as well as staircases are also exhibited. It is hardly necessary troubling you with the thickness of these as they depend upon the loads they have to carry.

This system has been a great boon in overcoming the difficulties experienced in the construction, and re-construction of overhead bridges, namely to get the necessary Head room without lowering the Railway line or raising the road level.

Finally, it is very evident from the number of works shown that a considerable saving in space through the lightness of the structures can be achieved.

QUICKNESS OF ERECTION.

Quickness of erection of a structure is often an essential factor in the building, or re-construction or means of communication, especially in cities.

At the Aqueducts erected for the Government Sewerage Department at Forest Lodge, N.S.W., an arch of 75 feet span and a length of carrier of 82 feet 10 inches were respectively built in one day.

A Bridge erected in Austria last year of 131 feet span, 14 feet 11 inches versed sine, 1 foot 2½ inches thickness at crown, and 1 foot 7½ inches near abutments, was finished in 15 hours, 180 cubic yards of Monier Mortar being placed in position in that time.

The overhead bridge erected on the deviation of the Southern Railway, between Hilltop and Colo Vale, by the Railway Commissioners was completed in 4½ hours, the bridge being 40 feet span, 23 feet wide, 8 inches thick at crown, and 1 foot at abutments.

During the erection of the shipping stores at Trieste, 600 sq. yds. of flooring, consisting of Monier Arches, filling in of haunches, and cement rendering were finished daily, the contract comprising a total area of 312,000 sq. yards, or nearly 65 acres.

COST.

With regard to the question of cost, there are so many varying conditions and circumstances to be considered, that it is scarcely advisable to enter into this matter further than to say that where iron, concrete and brick structures are necessary, this system will be found in the majority of cases to be much cheaper.

In conclusion, the Author drew attention to the report of Mr. C. W. Darley, Engineer-in-Chief for Public Works, and Mr. J. Davis, Engineer for Sewerage, attesting the undoubted success of Monier Constructions built at Forest Lodge, N.S.W. in connection with the Sydney Sewerage.

NO 1

Background data
PWD "Essays"

Baltzer on Monier Concrete

A factual report on the technical merits of reinforced concrete.



PROCEEDINGS
OF
The Engineering Association

NEW SOUTH WALES.

VOL. XII.

EDITED BY
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Hon. Sec. Eng. Assoc., N.S.W.

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moisten the materials, so that the mortar shows only a slight moisture on the surface when rammed in position. Mortar so mixed, forms better work than when a larger quantity of water is used. Sometimes fine gravel or screenings are added to cheapen the cost of the mortar, but this does not then of course adhere as strongly to the grill.

Round and oviform pipes and cylinders for bridges are manufactured on the Monier system, in various sizes from one foot six inches to six feet in diameter. Up to two feet six inches in diameter the pipes contain a single steel wire, which is sometimes wound eccentric; above that diameter they contain two concentric steel wires. The method of construction of the pipes is as follows:—A collapsible steel drum, oiled to prevent the mortar from sticking, is covered with a thin layer of cement grout and mortar. A layer of stout black wire netting is then wound and the ends fastened off, and over the netting a spiral wire is wound, and the whole covered with cement mortar; another spiral wire is wound, and the last coat of cement mortar put on. The pipes vary in thickness from one and one-eighth to two and three-eighths inches, and are light, strong and durable.

Various Monier pipes and cylinders, also the holes for the fish plates in the cylinders, are shown by the accompanying plate.

EXAMPLES.

PLATES.

Monier plates are used in lieu of buckled plates on an overbridge at Lindfield, North Shore line. The plates, four feet square, six inches thick at crown, and three inches at sides, simply rest on the flanges of the supporting girders, and are covered with metal.

SEWERAGE AND DRAINAGE PIPES.

These pipes, circular or oviform, are made in lengths of three feet seven inches, they are jointed by simply butting the pipes, and covering the joint with wire netting and a layer of cement mortar. They are strong to resist both inward and outward pressure, and are used for the same purposes as glazed earthenware pipes (sewerage drainage, stormwater, etc.) but they are not so liable to crack, and when cracked do not fall to pieces. Some twelve thousand lineal feet of Monier pipes of various sizes and shapes, have, up to February, 1901, been used in the construction of sewerage works in New South Wales, while about ten thousand lineal feet have been used to carry off stormwater.

PILE PROTECTION.

Pipes eighteen inches internal diameter for hewn piles, and twenty-one inch diameter for round piles, are used for protecting piles in tidal waters from the ravages of the torpedo, the protection extends from one foot above High Water Mark to six or eight feet below bed of river. The pipes are not cut by the drifting sand, or acted on by the sea water, and form a strong durable and efficient protection. The pipes are threaded around the piles, jointed up in one length, and then

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sunk to the requisite depth by the water jet, assisted in some cases with jacks. The joints are made with wire netting and cement mortar (2 of sand to 1 of cement), and the space between pile and pipe filled in with sand, except the top nine inches, which is filled in with fine concrete, and finished off with a concrete cap.

Some seventeen hundred lineal feet of twenty-one inch diameter pipes, and one hundred and thirty lineal feet of eighteen inch diameter pipes have been used up till February, 1901, in protecting the piles of bridges built in tidal waters.

CYLINDERS.

Monier cylinders are made from three feet six inches to six feet in diameter, about three feet seven inches long, and have proved to be an efficient substitute for cast iron at about one half the cost.

They are used for foundations of moderate depth, and may be sunk by open excavation, or under air pressure, the connections between the cylinders have been designed to withstand a head of water of forty feet. Each cylinder has several pairs of connecting strips built in, the number of which depend on the diameter of the cylinder; between these connecting strips in two adjacent cylinders a fish plate fits, and is secured to the connecting strips by steel wedges.

Red lead, bitumen and cork, and similar preparations are placed between the cylinders before jointing, to keep them watertight; pilot wedges are driven through the connecting strips to press the cylinders together, the permanent wedges are then put in, replacing the pilot wedges, and the holes around heads of wedges filled in with neat cement. Each bottom length of cylinder has a cast iron cutting edge bolted to it, and the cylinders in each pier are braced together with wrought iron bracing.

Monier cylinder piers have been sunk at Cockle Creek to thirty-six feet below water, and at the Wilson River, at Telegraph Point, to a similar depth; contracts have also been let for three other bridges in which they will shortly be used—Mulwarrie Ponds at Goulburn, Wyong Creek at Wyong, and MacIntyre River at Inverell—and so far, four hundred and seventy-seven lineal feet of three feet six inches diameter cylinders, one hundred and twenty lineal feet of four feet six inches in diameter, and seventy-two lineal feet of six feet diameter, have been constructed, or are in course of construction in New South Wales.

AQUEDUCTS.

The first Monier structures erected in New South Wales were the Monier aqueducts across Johnstone and White Creeks at Annandale. They were erected in 1897 by Messrs. Carter, Gummow & Co., for the Sewerage Branch of the Public Works Department, under the direction of Mr. J. Davis, Engineer-in-Chief for Sewerage Construction.

The aqueducts carry the main northern sewer for Annandale and Leichhardt, they are similar in design and connect with sewer tunnels at each end. There are seventeen arches in all, seventy-five feet clear span, and eighty-two feet ten inches from centre to centre of piers. The arches are twelve inches thick at crown, and fourteen inches thick

1900

Cockle Ck
(MR 1973)

(MR 1973)

both replaced

all replaced

NB

None in the bed

at springing, with a grill of iron bars near the intrados, three inches square mesh, carrying bars three-eighths of an inch in diameter, and distributing bars one-quarter inch diameter, a short length of grill extending twelve feet from each pier, is also placed at the extrados of the arch.

The Monier arches are built of cement mortar 3 to 1, but the small jack arches and aqueduct are built of bluestone concrete. The Monier arches were built from pier to pier each in one day, and bases left on the extrados to form footings for the concrete piers carrying the jack arches. The aqueduct was then built on these jack arches, and expansion joints left over each main pier.

As these works were of a novel character, and the first of their kind in Australia, the Contractors were required to maintain them for three months, after erection, and further to guarantee to remove and replace them by suitable structures, if any defects were found within a period of three years. This period has now expired, and the structures have proved satisfactory.

BRIDGES.

A road bridge on the Monier principle has just been completed over Read's Gully, Main Northern Road, by the Bridges Branch of the Public Works Department, at a cost of £480.

The arch is about thirty feet span, six inches thick at crown at ten inches at abutments. The carrying bars are three-eighths of an inch diameter, spaced three inches centres, and distributing bars a quarter of an inch diameter, spaced four inch centres, and the grill is tied at each point of intersection with No. 22 B.W.G. black wire, the overlap of the bars is twelve inches, tied in three places with double wire. The bridge is shown by the accompanying Plate.

The scaffolding consisted of gauged timber, planed on one side with sufficient space between the planks to allow them to swell freely when wetted; templates cut to the exact thickness of the arch were then nailed on either side of the scaffolding.

The grill was supported on small pads of cement mortar placed irregularly on the surface of the scaffolding to keep the grill in its proper position. The cement mortar (3 to 1) was spread in two layers, the lower one about one and a quarter inches thick, was rammed between and completely covered the grill, the upper layer was of the requisite thickness to bring the mortar to the top of the templates. It is essential to keep the lower layer about one foot in advance of the upper one, so that the unfinished ends form steps for jointing, and the work must be finished between the supports without any intermission.

The arch was tested with a one sided load of eighty-seven pounds per square foot, consisting of wet sand, and did not give the slightest deflection.

An overheard bridge consisting of three forty-two feet spans, eight inches thick at crown, has been erected by the Railway Commissioners at Stratfield station, partly to carry the road traffic, and partly to support the new station buildings.

Several bridges have been erected on the Monier principle in Victoria. The bridge across the Yarra (see Plate), consists of three spans each ninety-five feet in the clear, carrying a roadway eighteen feet wide, and two footways each six feet wide. The rise of each arch is

twelve feet seven and-a-half inches; thickness at crown, sixteen inches; at abutments, twenty inches. The arches are built of 3 to 1 Portland cement mortar, and contain two lattices, one at the intrados, and one at the extrados consisting of three-eighths inch carrying bars, and quarter inch distributing bars. The total width of the bridge is thirty-two feet over all, and was built in three sections, each outer one eleven feet wide, and the centre section ten feet wide. Centering twelve feet wide was erected the full length of the bridge, and one of the outer sections built across the three spans in three consecutive days, the strip for each arch being built in one day. It was allowed to set for twenty-eight days, and the scaffolding removed and erected for the other outer section, which was built and allowed to set as before; and whilst each outer section was setting, its parapet and spandril wall was built. The outer sections were built with sloping inner edges to wedge in the centre section, the rods of the outer sections also projected. When the second section had set, the scaffolding was removed and erected for the centre portion. The lower grill was then put in place, and connected to the projecting rods of lower grills in the sections already built. The sloping faces of the finished portions were picked over and well rubbed with neat cement grout, and the mortar for the centre portion put in, up to the level of the upper grill, in two layers; the upper grill was then fastened to the projecting ends of the rods, and the remainder of the mortar rammed in place. Each arch took three days to build, or nine days for the whole superstructure. The bridge was tested with a sixteen ton steam roller, and the temporary deflection in no case exceeded one-sixteenth of an inch. The bridge was also tested with a uniform load of one hundred pounds per square foot of roadway and footway, with about the same deflection.

Whireler's Creek Bridge, near Creswick, Victoria, consists of two seventy-five feet spans, rise sixteen feet six inches; thickness at crown, twelve inches; at abutments, fourteen inches. The arches are built of cement mortar (3 to 1), and contain an upper and lower grill of three-eighths inch, and quarter inch bars.

Moorabool Creek Bridge, Geelong, consists of three spans, two of sixty feet, and centre span of one hundred feet, with versines of nine feet four inches and fourteen feet respectively. The sixty feet spans are eleven inches and fourteen inches thick at crown and springing, whilst the one hundred feet span is fourteen inches and twenty inches. Each arch contains two grills consisting of three-eighths inch and a quarter inch bars.

RESERVOIRS.

One of the first applications of the Monier system of construction in Europe, was the building of circular tanks and reservoirs up to sixty feet diameter. The first example in New South Wales of this class of construction is the service reservoir at Kiama, designed by Mr. C. W. Darley, Engineer-in-chief for Public works, the Monier portion of which was completed at a cost of £750 (see Plate).

The reservoir is thirty-two feet diameter, sixteen feet high, and when filled within nine inches of the top, has a capacity of one hundred and ninety-two thousand gallons.

52 in dia paper

SOME NOTES ON MONIER CONSTRUCTION,

BY

JOHN J. C. BRADFIELD, M.E., ASSOC. M. INST. C.E.

(Sydney University Engineering Society.)

ABOUT twenty years ago, a novel system of construction was invented by one Jean Monier, and is now known by his name. The system, viz: a combination of cement mortar and iron, was perfected by two German engineers, Wayss and Koenen, and thoroughly tested by the "Austrian Society of Engineers and Architects." These tests proved its great strength, durability and fire resisting properties.

Cement mortar and iron are in appearance very diverse materials, but they have some physical features in common, and when used conjointly, form a strong elastic and almost homogeneous mass, well adapted for works of construction.

Cement mortar is cheap, durable and readily moulded to any required shape; its compressive strength, however, is at least ten times as great as its tensile strength, and when subject to bonding moments, it is impracticable to develop the full compressive strength, and at the same time provide the necessary area to resist the tensile stresses. In order therefore, to develop the full compressive strength of the mortar, it has been found necessary to augment its tensile strength, and thus decrease the total area of section, which would otherwise be required.

For cement mortar (3 of sand to 1 of cement) the average compressive strength is about two thousand pounds per square inch, and tensile strength, two hundred pounds, or a ratio of 10 to 1.

Experiments and experience have proved that wrought iron or steel bars are best adapted for this purpose, the ratio of the tensile strength of wrought iron and cement being about 250 to 1.

The chief features of this combination of cement and iron will now be briefly described:—

EXPANSION.

The expansion and contraction of cement mortar and iron are about identical. For a range of temperature of 100° C. or 180° F., the coefficient of expansion of cement mortar is from .00137 to .00148, whilst for iron it is from .001235, to .00145, so that the combination may be taken as expanding and contracting as one mass.

Journal
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Abstract of Proceedings
for 1900
of University Engineering Society
New South Wales

Vol V

Amundale
Aqueducts

— Bldg Eng Min Ind Jan 1901 p26

Apr 11 1895 contract Dept PW & Carter Gunnison & Co for const
2 aqueducts across Johnstones' & Whites Cks using Monies system.
£15500. JCK 940' WCK 1040' arches 82'10" etc 38'
above cks network of $3\frac{3}{8}$ " @ 3" and $\frac{1}{4}$ " cross iron bars.
Normal maintenance period 3 months, system adapted is of
a novel character, felt prevalent for contractor to give
a substantial security. Special bond £12000
then 3 year maintenance period as from Dec 31 inpection
of Aug 19 1897. Performance satisfactory and well
be handed over to the Water Board.
But is not to be mentioned in the 1st.

in relation to Engineers Australia Transactions (1922)

tinuance of existing conditions—viz., leaving the inland areas to the graziers, as one hears advocated—meant that in time these areas would all become valueless. With the irrigation settlements as a standby, there were grounds for supposing that closer settlement could be induced on adjoining dry areas. Only close settlement would, in the author's opinion, prove an effective check to prickly-pear.

Increased railway and other State revenue, decentralisation, provision against the effects of uncertain weather conditions which so greatly handicap rural industries, were other collateral advantages of irrigation. Rural conditions under close settlement were pleasanter than ordinary bush life, and with plenty of water could be greatly improved, so that irrigation in Queensland would assist to check the drift of population to the cities.

** Genesis and Development of Reinforced Concrete in Australia.*

By GERALD WILKINSON MITCHELL, (Member). (Read before Sydney Division, 11th May, 1922.)

This paper was intended as a contribution to the history of engineering in Australia, with special reference to the subject of reinforced concrete.

The first mention of concrete reinforced by steel or iron rods on a scientific basis was made in Sydney by Mr. W. J. Baltzer, a civil engineer, who was at that time an engineering draftsman in the Public Works Department of N.S.W. He made a study of the subject on information received from Germany and Austria, where it was being developed on scientific lines, after its humble origin by J. Monier in France. In 1895, Mr. Baltzer produced a typewritten book with drawings (the first book on the subject produced in English) and placed this information before the Engineer-in-Chief for Sewerage. He keenly interested himself in the new combination of materials and quickly grasped its great potentialities, and it was without doubt, owing to his wide vision and foresight, that Australia was given its first opportunity of practically demonstrating the value of what is known as Reinforced Concrete.

It was in this year (1895) that the Minister for Public Works called tenders for the north-western branch of the sewerage of Sydney, extending from Forest Lodge towards Balmain, with two large aqueducts designed in brick and concrete, and allowed Carter, Gummow and Company to submit an alternative tender for this work on the Monier system. Their price being the lowest, this tender was accepted conditionally that if the Monier arches and aqueducts failed the Department was not to have any financial loss, and the Department further safeguarded itself with a period of maintenance supplemented thereafter by a bond from the contractors and bondsman for three years, for the sum of £12,000.

Director-General PWD at time Govt took over Monier Pipe Works.

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Sewer aqueducts

The arches of these aqueducts were of 82ft. 10in. centres of piers and 9ft. 3in. rise, with a thickness of 12 inches at crown and 14 inches at springing.

In 1896, Mr. Baltzer brought to Australia the first machine for making Monier pipes, which was the nucleus for the establishment of an industry that grew into large dimensions and was finally taken over as an industrial undertaking by the New South Wales Government.

It was not till 1897 that the Monier system was first introduced into Victoria.

Amongst the architects it was slow to receive support, and it was not till 1898 that the first flat floor was carried out.

In 1897, the making of Monier pipes on a small scale was commenced in Sydney, but it was found that the European system with wire-netting embedded in the centre of the concrete, although giving greater elasticity to the pipe, did not greatly increase its breaking strength under external loads. The design of the pipes was therefore carefully investigated after numerous tests and was made the subject of fresh patents. These were the basis of the Monier pipes of to-day, and it may be mentioned that the scientific designs patented in this country were embodied in patents some two or three years later by the United States and Germany, two countries in which a patent had value; a fact that showed that in this section of the use of reinforced concrete scientifically, Australia was ahead of other countries.

From this time the use of Monier pipes for sewerage and stormwater drainage became general, and the output of a standardised article was rapidly increased.

In 1898, the first arched culvert was built under a road at Blandford for the Public Works Department, and about the same time the design of service reservoirs on the system received practical application. The first work carried out was the service reservoir at Kiama, which was constructed in 1899; its dimensions were 52 feet diameter and 16 feet high, the thickness of the walls at the base 7 1/4 inches and 2 1/4 inches at top.

The Monier pipe was now becoming well known, and its value recognised for other purposes than stormwater and sewerage works. In 1899, Mr. E. M. de Burgh conceived the idea of using these pipes to protect timber piles against the inroads of the teredo. The first Monier pile armour was manufactured to his order for the road bridge at Cockle Creek.

In the same year, the first oval pipes were made for the late Mr. Mansfield to use in the construction of a stormwater drain under Messrs. Lever Bros.' works at Balmain.

In 1899, the system was first applied to wall construction at Paramatta Gaol, and a house foundation was carried out in Birrell Street, Bondi.

In 1903, a large T beam was designed and tested at New-castle for the Railway Commissioners.

In 1902, the first rat-proof walling was carried out with Monier plates, and later on reclamation works were constructed

Check City Council

Pipes

UB

Check with DM R

Kiama water reservoir

Plate in Bradfields paper

Check DM R Yes, MKATZ

See Gummow paper

Superior Portland Cement

by manufacturing portable reinforced concrete sections called trestles, which were found to be most economical and effective. Another direction in which this material was adopted was in the construction of lighthouses, or beacons, at various points in Sydney Harbour.

In 1904, the Public Works Department built a flood-proof low-level bridge at Richmond over the Hawkesbury. About this time many large structures were built in New Zealand, notably the wharves in Auckland Harbour and the Grafton Bridge.

The most notable development of recent years had been the manufacture of pipes by centrifugal action under the Hume patents. Pipes had been made to stand a head of 700 feet of water, and were being used in Tasmania under a working head of 400 feet, plus friction and pipe hammer.

Radical changes had taken place in the method of mixing the concrete for reinforced work as well as the component parts of the concrete itself. In the early days no metal aggregate was used in the Monier concrete, which was entirely composed of 3 to 1 mortar. This was mixed very dry and, in order to get the requisite adhesion, was rammed into position round the steel bars. Although information in the way of tests was available to the pioneers of this industry that reducing the sand and adding metal would give, if anything, a stronger mixture without reducing the adhesion and moreover would be cheaper, they were not prepared to adopt it on account of the big financial responsibility they had to shoulder and could afford to take no risks by deviating from the recognised rules laid down by the European engineers. It was only after they had gained their own experience and confidence they saw that better results would be got by reducing the sand and making a mixture of cement, sand, and metal instead of sand and cement only. One of the great drawbacks in using the 3 sand to 1 cement mixture, or mortar concrete, as it was called, and ramming it into place, was that it required a much stiffer centring as the ramming used to distort it and loosen the wedges, requiring extreme and constant watchfulness to see that the centring was not displaced. Gradually the amount of metal aggregate was increased, as knowledge accumulated, till the recognised mixture for ordinary reinforced concrete work all the world over was 1 part cement to 2 parts sand to 4 parts hard metal, 1 inch to 3 inch gauge. Of course, for special work where water tightness or high compressive strength was required, i.e., for columns where it was necessary to keep the dimensions within bounds, richer mixtures were used.

With regard to the amount of water that should be added to concrete mixtures in ordinary work, opinions were very divided. Laboratory tests tended to prove that the least amount of water over and above that required for the chemical reaction necessary for the setting of the cement gave the best results, and this fact was now beyond any doubt. But in dealing with this question the personal equation came in, because the ordinary intelligent labourer working on a concrete job could not be expected to exercise the same care as the man

preparing a test subject in a laboratory. In reinforced work the concrete must be put into position in such a way that the resulting work would give the greatest amount of adhesion between the concrete and steel without impairing the compressive strength of the concrete, and in positions where water tightness was required this must be secured as well; experience showed that the only safe way this could be done was to use wet or sloppy mixtures in preference to dry mixtures.

An example of the danger in using dry mixtures was the destruction of the Mittagong Reservoir, 1909, when it was proved that the cause of failure was the use of dry mixtures which did not give the required adhesion, and consequently the reservoir collapsed. The wet mixture could be much more easily and economically placed than the dry one, and consequently there was danger that the water constituent could be overdone, and this should be guarded against. It was not possible to lay down any rules or specify the quantity of water that was to be used, as too many circumstances had to be taken into consideration, such as temperature, quality of aggregate, position in which concrete was to be placed, &c. When the concrete was of any depth the amount of water should be considerably varied during a day's work, as the spading, ramming, and punning of concrete brought the water to the top, and consequently drier mixtures were required to take up the excess water. Centring and moulds had a great influence on the amount of water that should be used, metal moulds not requiring as much water as timber where a good deal of water escaped through the timber joints, besides being absorbed by the timber. Methods of hoisting and shooting where the fluidity could not be altered should be sparingly used.

Mixing by hand from 1902 onwards had gradually given place to machine mixing, and although this latter was not directly cheaper than hand-mixing, it reduced the number of men required; and on jobs that were not concreting continually it avoided the constant increasing and reduction of hands due to the concreting programme. The machine-mix was, of course, better and of more even quality than could be expected from hand-mixing. It might not be out of place to say that only Batch mixers should be allowed, and the author would, from his own experience, rather have hand-mixing than concrete from continuous mixers. The continuous mixer might be reliable if all the materials were always in the same physical condition, which, as a rule, was not practicable. On outside jobs, on account of the sand and metal being wet in the morning and gradually drying, it might be necessary to alter the machine four times or more during the day to give the required proportions. The Batch mixer, on the other hand, had the material measured before going into the drum, and the proportions would therefore not vary whether the materials were wet or dry. In a Batch mixer it would be an advantage to have the materials wet, as this would considerably reduce the time required to give a proper and sufficient mix. This was offset to some extent in the greater difficulty in getting the batch to slip from the hopper into the drum. Speaking broadly, a good mix would take from three-quarters to two minutes. After

Weld
Bony

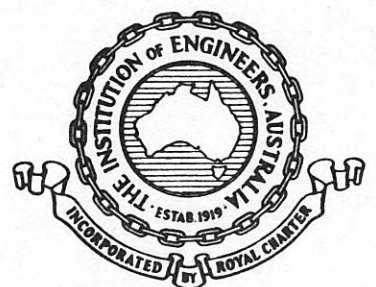
DMR and
8047 project

*The
Institution of Engineers,
Australia*

*Annandale Aqueducts,
Sections 4.2 to 4.5*

Early Reinforced Concrete in New South Wales (1895-1915)

D.J. FRASER, M.I.E.Aust.



Early Reinforced Concrete in New South Wales (1895-1915)

D.J. FRASER, M.I.E.Aust.*

SUMMARY: Reinforced concrete construction began in Europe around 1870, soon after Joseph Monier took out patents for concrete flower pots reinforced by wire netting. The Monier System, as it became known, was extensively used in Germany where it was refined to a viable, economical structural material for a wide range of applications. It was not until the early 1890's that the Monier System was introduced into New South Wales and then with some initial hesitancy and controversy about its use. But after the success of its first major application, the sewer aqueducts in Annandale, Sydney, 1895-97, its development and use grew rapidly. Within the next twenty years, Sydney's structural engineers became as proficient in the theory, design and application of this new technology as their counterparts in Europe, England and America. This paper traces the history of reinforced concrete in New South Wales during those formative years.

1 INTRODUCTION

The use of reinforced concrete in New South Wales began in 1895 when Carter, Gummow & Co. were awarded Contract No. 77 by the Public Works Department for the construction of two concrete sewer aqueducts across the valleys of Johnstone's and White's Creeks Annandale, Sydney. At the time, reinforced concrete was known by other names such as ferro-concrete, concrete iron and steel-concrete construction, and by the names of patented methods such as Hennibique, Thacher and Melan Systems. The Annandale aqueducts, figure 1, were built using the Monier System of reinforced concrete arches. These aqueducts are still in service after 87 years.

The first reference to the introduction of the Monier System into New South Wales was not recorded in contemporary technical papers but in the unusual source of the Report, Evidence and Appendices of a Royal Commission (1896-97). The Inquiry was initiated by accusations in the Colonial Parliament that Robert Hickson, Under-Secretary for Public Works, had shown favouritism towards Carter, Gummow & Co and had allowed irregularities in the contractual procedures at a cost to the Crown.

Legally, nothing came out of the Inquiry. Charges were not proved and Hickson and his officers were exonerated. To this extent the Inquiry followed tradition and had been largely "a waste of time and money". But what did come from the Inquiry is a priceless record of the beginnings of reinforced concrete, specifically the Monier System, in New South Wales. Reported fully and contemporaneously, it is information that might not otherwise have been recorded, because subsequent technical papers concentrated on the theory and use of reinforced concrete and only briefly mentioned its origins.

When the two sewer aqueducts were completed in 1897, they were the first large-scale use of reinforced concrete in New South Wales and, in fact, in Australia. Together with John Monash's work in Victoria, the Fyansford and Anderson Bridges, and the 1896 Lamington Bridge in Queensland, these projects

established reinforced concrete as the new building material. The emergence of the new technology coincided with the emergence of a new nation, a federated Australia.

Local engineers were quick to recognise the merits of reinforced concrete because the examples in Europe, Britain and America clearly demonstrated its flexibility of application. During the first twenty years of use in New South Wales, a great variety of works were constructed using the Monier and other systems.

This paper presents an historical review of the origins of reinforced concrete and its use, with specific reference to New South Wales and the period 1895 to 1915. The quality of construction was such that a great many of those early projects are still in use and are accessible for inspection. With many of the surviving works 80 or more years old, and with reinforced concrete currently dominating most forms of construction, these early projects have become part of our engineering heritage.

2 HISTORICAL BACKGROUND

Strengthening (reinforcing) masonry and concrete constructions, so as to resist the internal tensions that cause joints to open and cracks to appear, is a very old concept. The Romans are known to have embedded wood, brass and iron within their structures for that purpose, and the practice of including granite keys, metal rods and cramps in stonework, figure 2, was in common use during Medieval and Renaissance times. One of the largest and best examples of the application of this concept is Sir Christopher Wren's use of iron chains around the base of the dome of St Paul's Cathedral to help the concrete resist the tension caused by the outward thrust (Jones and Lakeman 1913, Building Research Station 1956, Cowan 1977 and 1978).

However, the useful principle of combining the high crushing strength of concrete and the high tensile strength of iron into a composite structural material, had to await the availability of cements, hence concretes, that were alkaline and reasonably water-proof thereby forming a reliable protective cover to the iron or steel. This did not occur until the nineteenth century. In 1824 Joseph Aspdin patented his method for making "portland cement" and this new

Dr D J Fraser is a Senior Lecturer, School of Civil Engineering, University of New South Wales. (Paper G1173 submitted on 19 April 1985).

In the second half of the nineteenth century, technical inventions were pouring out of people's minds, off the drawings boards and out of the

3 PATENTED SYSTEMS

A more complete history of reinforced concrete (American Concrete Institute 1976, 1982) is beyond the scope of this paper because this brief review is sufficient background to its main theme.

Meanwhile, parallel developments had taken place in France where Edmond Coignet and Francois Hennebique made significant contributions to the theory and practice of reinforced concrete. Whereas the Monier system was based on the concrete arch in which tension was generally a minor problem, Coignet and Hennebique concentrated on beams and floor slabs in which high tensile stresses made the use of iron or steel reinforcement essential. Their patents of 1906 and 1897, figure 5, have all the characteristics of modern reinforced concrete construction. Subsequent changes over the next twenty years were mainly refinements to the theory and to the details by academics and engineers in Europe, Britain and America.

This German connection is very important to the introduction of reinforced concrete to Australia because the early exponents, J. Baltzer, F.M. Gummow and John Monash were fluent in German and were ideally placed to exploit the new technology in New South Wales, Victoria and South Australia at the end of the nineteenth century.

In 1879, Monier sold his inventions to G.A. Weyss whose firm of Weyss & Freitag of Frankfurt-am-Main, Germany, made widespread use of them in Germany and Austria-Hungary. A series of strength and durability tests was carried out for him by K. Koenen, figure 4, and a manual was published in 1886 called "Das System Monier". There was now sound theoretical and experimental support for Monier's empirical designs, and Weyss succeeded in introducing the Monier system into public works. Between 1887 and 1891 the firm built 320 arched bridges, some of them with spans up to 40m (130 feet), figure 4.

Monier was a gardener in Paris and was manufacturing gardening tools and appliances such as clay flower pots. When the substitution of concrete still left the finished product brittle, he added a skeleton of iron wires to the moulds and produced durable tubs that were shatter-proof. In 1867 he patented the invention and displayed examples at the International Exhibition in Paris the same year. During the next five years he took out patents for pipes, arch bridges, beams and reservoirs.

By 1855 there were two specific examples of this composite form of construction that should have alerted others to the usefulness and range of its application. J.L. Lambot built a reinforced concrete rowing boat in 1848 and displayed it at the 1855 International Exhibition in Paris, and W.B. Wilkinson constructed suspended concrete floors reinforced by wire ropes, figure 3, in Newcastle-on-Tyne, which he patented in 1854. But it was the maker of flower pots, Joseph Monier, who set in train the events that led to the development of reinforced concrete as twentieth century engineers know it.

Marc Isambard Brunel's Thames Tunnel. But it was not in general use until some years later because it was confused with gypsum or "plaster of Paris" which quickly rusted the embedded iron.

EARLY REINFORCED CONCRETE IN NSW — Fraser

After Monier took out his patents, the usefulness of the new composite material was immediately recognised, but the problem was how to use the new material without paying royalties or facing legal challenges over infringements of the patent rights. The solution lay in the fact that the concept of reinforced concrete could not be patented, only the method by which it was achieved could be patented (the same applies to prestressed concrete today). Consequently, during the thirty-year period 1870-1900, a great many systems for reinforcing concrete were patented, Table 1.

TABLE 1

SOME PATENTED SYSTEMS FOR REINFORCED CONCRETE

Allen	Brannon	Clinton
Coginet	Considerere	Corr Bar
Cottacin	Dennett	Dentile
Expanded Metal	Hyat	Hennibique
Keedon	Johnson's Lattice	Kahn
Keedon	Klett	Koenen
Lock-woven Mesh	Melan	Moller
Monier	Paragon	Ransome
Scott	Shaler	Thacher
Triangle Mesh	Visintini	

In each case the patent referred to the types of bars and their arrangements, figure 6, as the names Indented Bar and Triangular Mesh suggest. Companies were formed to market many of these patented systems and a host of Manuals and Catalogues (Mouchel 1909, American Steel & Wire Co. 1909, Indented Bar and Concrete Engineering Co. Ltd. 1916) were made available to all potential users. However, by the end of the period under review it was realised there was no valid patent preventing the use of plain reinforcing rods in any formation, consequently, specialist firms came to rely more on their skill and experience rather than their patents (again a parallel situation with pre-stressed concrete). As for the early years of reinforced concrete in New South Wales is concerned, the dominant systems appear to have been Monier, Hennibique, Indented Bar and Clinton-Paragon.

4 THE START IN SYDNEY

4.1 The culvert at Burwood

Although the Annandale sewer aqueducts of 1895-97 were the first major use of Monier arches, a small Monier arch had been constructed in 1894 for a stormwater culvert, figure 7, located under Parramatta Road, Burwood between Wentworth Road and Phillip Street. A drain of similar proportions is there at present, but the records of the Burwood and Concord Municipal Councils do not indicate whether it is the original culvert.

In 1894, the District Engineer for the Public Works Department was W.A. Smith. He stated in evidence to the Royal Commission that the culvert had been built as an experimental arch by Carter, Gummow & Co., and had cost about half the estimated cost of standard brick construction. The Monier culvert had been "tested by a severe strain" and the system had many advantages over conventional forms of construction. The Commission reported "that a moving load across an arch causes bending in other parts of the arch, sometimes flattening the curve of the arch, sometimes increasing the curvature of the arch. The iron adds strength to the arch by the added quality of a

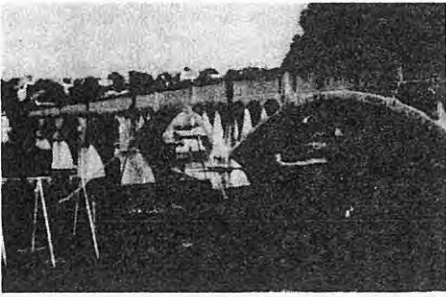


Figure 1 Johnstone's Creek aqueduct, one of the two 1896 sewer aqueducts in Annandale, Sydney.

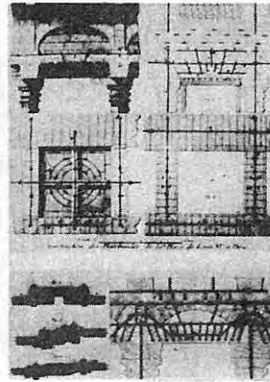
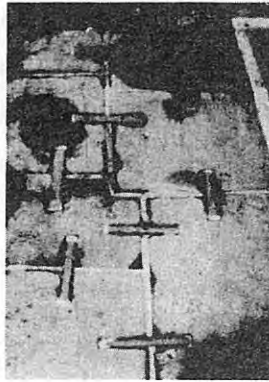


Figure 2 Examples of reinforcing masonry construction during the period 1650-1850.

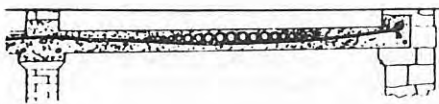


Figure 3 Wilkinson's 1854 patented floor. It incorporated wire ropes for tensile strength and clay pipes to reduce self weight.

Figure 4 In Germany, a series of load tests was carried out on Monier arches. The success of the tests led to the construction of many large slender arch bridges throughout Europe.

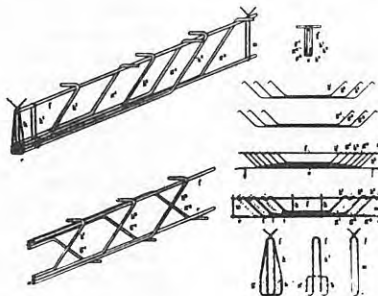
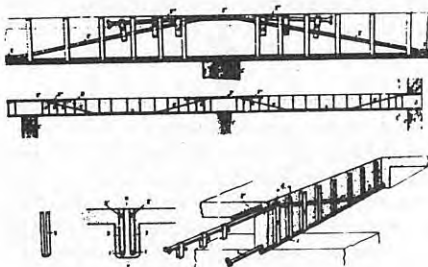
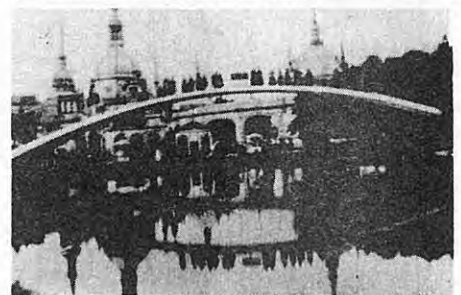
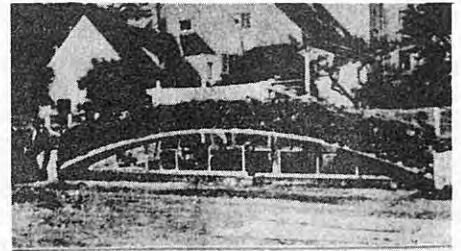
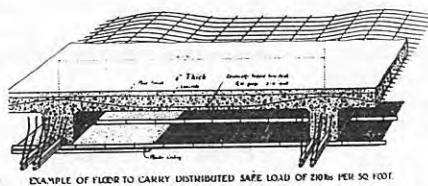
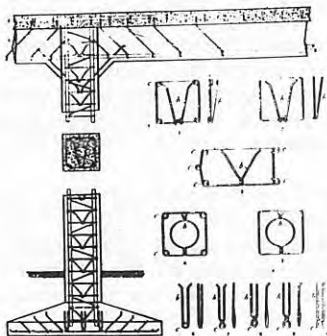


Figure 5 By the early twentieth century, reinforced concrete had acquired many of its modern features as these 1897 and 1906 patents show.



EXAMPLE OF FLOOR TO CARRY DISTRIBUTED SAFE LOAD OF 200 lb PER SQ FOOT.

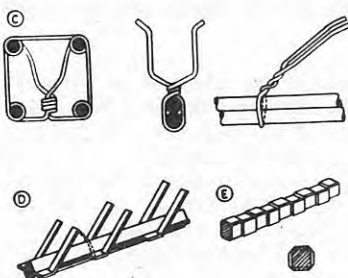


Figure 6 Early reinforced concrete was characterised by a flood of patents such as the Paragon System (top left) and the Clinton Floor (above), and (C) the BRC hoop and stirrup, (D) the Kahn Bar and (E) the Indented Bar.

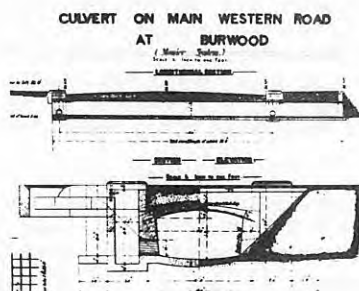


Figure 7

A modest stormwater culvert constructed in 1894 under Parramatta Road, Burwood, using the Monier System began reinforced concrete in New South Wales.

girder. Loads can be imposed at any point".

Robert Hickson, Commissioner for Roads and Bridges, and Engineer-in-Chief for Sewerage Construction, reported on 18 July 1894 "that the culvert was very satisfactory and that he had a firm belief in the system; schemes using the system would be successful, strong and graceful". He was therefore anxious to give it a fair trial and put into practice this "new departure in engineering". Consequently, when the tenders for the Annandale Aqueducts were reviewed, he approved on the 16th May, 1895 the awarding of the contract to the agents of the Monier System, Messrs. Carter, Gummow & Co. plus the payment of a 15% royalty.

4.2 The Inquiry

Hickson's actions led to a furore in Parliament. During construction of the aqueducts, Varney Parkes, MLA alleged "favouritism, defective work, incompetence, violation of terms of contract, and insufficient bond", was critical of the "speciality" nature of the design and expressed a lack of confidence in the ability of those involved to carry it out properly. The Royal Commission was appointed on 21 May, 1896.

The Commission heard evidence from a wide section of concerned parties, politicians, government officers, engineers of the Public Works Department, Contractors, Professor W.H. Warren and consulting engineers such as Norman Selfe.ittings occurred during the twelve months after its appointment and its final Report was issued late 1897. Hickson and his officers were completely exonerated, indeed some of the original allegations were withdrawn early in the proceedings and the Commission "hinted" that the others were frivolous and precipitated by malice.

To that extent, the Inquiry could be seen as a waste of time and simply a standard ploy of politicians; but in calling all the expert witnesses to give evidence and receiving detailed technical submissions, the Report contains a priceless history of the beginnings of reinforced concrete in New South Wales.

4.3 Introduction of the Monier System

The Report and Evidence of the Royal Commission indicates that W.J. Baltzer, a draughtsman/engineer with the Sewerage Construction Branch of the Public Works Department, initiated the use of Monier construction in Sydney, and, it seems, to Australia. He had received his engineering education in Germany and had joined the Department in 1885. He was regarded as a resourceful and capable officer who had designed some major works but, owing to the severe economic depression of the early 1890's, was retrained in 1895 "with great regret" (Hickson's evidence).

Baltzer had a relative in Germany who was a Professor at the Technical School, Berlin, whom he had visited sometime around 1890. During the visit he toured Germany looking at engineering works and took photographs of many of the Monier arch bridges. When he returned to Sydney he had a letter from the Monier Company (Wayss & Co.) offering to afford him every information.

During 1892-95 Baltzer compiled a set of notes (Mitchell 1922) about Monier construction which subsequently became the 1896 Treatise issued by Carter, Gummow and Co. (see later). It is not clear from the Commission's Report if Baltzer was responsible for the design of the culvert at Burwood, but the inference

is strong, however there is no doubt that he designed the viaduct of Monier arches for the Annandale sewer aqueducts.

4.4 The Annandale Aqueducts

Annandale is an inner western suburb of Sydney, located on the southern side of Rozelle Bay and bounded by Parramatta Road further south. Its best known street is the wide, gracious Johnson Street which runs straight from the bay to Parramatta Road along a ridge. To the east is the valley of Johnstone's Creek and to the west is White's Creek; both creeks flow northwards into Rozelle Bay.

During the 1880's Sydney was expanding rapidly due to the boom conditions and the large influx of immigrants. Public works, such as water supply and sewerage schemes, were a major feature of those hectic years. When the large sewer main was planned in 1893 to drain most of the suburbs on the southern side of the Harbour to the Bondi Outfall it was found necessary to carry a branch sewer across Johnstone's and White's Creeks, Contract No. 77.

The original PWD design, figure 8, proposed a series of brick arches for each aqueduct with a total length of about 610m (2000 feet) by 1m (3 ft 6 in) wide and at an estimated cost of £11,298 (Warren).

By 1895 the agency for the Monier System was held by Carter, Gummow and Co., a successful firm of contractors, who retained Baltzer as a consultant at a fee of 2½% of any Monier-related contract. He prepared an alternate design for them "out of office hours" based on 25.3m (82 feet 10 inch) Monier arches, figure 8, supporting a reinforced concrete flume at an estimated cost of £9,203. Carter, Gummow and Co. were awarded Contract No 77. Baltzer, of course, was still employed by the Department and so was seen to be in a compromising situation. This was another factor that precipitated the Inquiry.

The Monier arch design was seen by some as being a "speciality" and there were expressions of lack of confidence in the viability of the system and in the experience of all those involved in the project. But these "fears" were dismissed by the support from the overwhelming amount of evidence, for example, Baltzer and his credentials, Monier construction in Germany, the experimental culvert at Burwood, test arches loaded to destruction by Carter, Gummow at Forest Lodge, and the technical evidence by Prof. W.H. Warren and Norman Selfe. Hickson stated that "it was good for the Department to accept the substitute tender and so get valuable experience in this form of construction". Indeed it did, as later works described in this paper show.

Another important factor in the acceptance of the cheaper Monier arch design was the financial climate of the time. New South Wales was still suffering from the deep economic depression 1892-93, therefore, a project that offered substantial technical benefits with a saving in costs of about 20% was welcomed enthusiastically by those responsible for planning and constructing public works during those difficult years.

But did the Colony get value for its money despite the cost advantage of the Monier scheme? The unit cost of the aqueducts was £1.3 per ft² in 1896. When indexed to 1984 (Pope 1984) the unit cost is \$1060 per m² which compares favourably with current estimates of between \$1200 and \$1400 per m². So the Monier System appears to have been cost-effective and the decision to adopt the new technology was justified. However, it was not seen that way in 1896.

The contractors had to agree to £5,000 retention money and maintain and fully guarantee the completed aqueducts for three years. The onus of satisfactory performance of the structure was placed squarely with the contractors.

4.5 Carter, Gummow and Co.

The principals of this company were mainly contractors, Messrs. Carter, Forrest, Snodgrass, Maddison and Ewing. F.M. Gummow and W.J. Baltzer (by retainer) were the engineers. The Company had been formed in 1892 and had successes with many projects including the Martickville sewer scheme covered by Contract No. 69. Later on, Carter, Gummow and Forrest became the only principals. In 1896, Baltzer brought to Australia the first machine for making Monier pipes and the Company produced a Treatise (Carter 1896) containing a complete review of the Monier System including photographs and drawings showing the scope of application of this form of reinforced concrete. Making Monier pipes soon became the dominant part of their activities (Gummow 1899) and the new firm of Gummow, Forrest & Co. established the Monier Pipe Factory, figure 9, at Alexandria. Eventually, the Government acquired the works in 1914 (PWD Annual Report, June 30, 1914) and continued business as the State Monier Pipe and Reinforced Concrete Works.

F.M. Gummow, figure 9, was a graduate in Civil Engineering from Melbourne University and by the time of constructing the Annandale aqueducts in 1896 he had some thirteen years of practical experience. Starting at 21 years old he had worked on the Bondi sewer, the Hyde Park sewer, excavations at the Potts Hill reservoir and other similar works in Sydney. In 1892 he was awarded his first contract for water supply works in Adelaide. From 1893 he was a principal with the companies noted earlier and their projects. One of their most successful departures from Monier construction was building the Dunolly Ford Bridge over the Hunter River at Singleton, figure 9, during 1904-05 (Dunolly Ford Br. Souvenir, 1905).

5 THE MONIER SYSTEM

The definition of Monier construction seems mundane today, but ninety years ago this new material was viewed with more interest. It had a degree of novelty because it had figured prominently in the Inquiry, so much so that the popular newspaper "Town and Country Journal" carried a feature article about it in the issue of October 10, 1896. Extracted from Gummow's Treatise of January 1896, the article said, "The system of construction consists of iron rods placed longitudinally and laterally to form a mesh or lattice. The sectional area of the rods and the size of the lattice used, vary with the requirements of the structure, and are ascertained from formulae founded on practical experiment. The lattice is erected on centring and cement mortar is well rammed through and around it. In setting, the mortar shrinks and gets a firm grip of the iron. The lattice work is calculated to take up and distribute any tension the structure is likely to be subjected to, and it gives elasticity to the body".

The article continued in this flowery style as it mentioned the advantages and applications of the system and quoted some successful examples in Germany.

So new was this technology that it did not appear in Professor Warren's text book of 1894, and there seems to have been an air of mysticism and complexity about it among contemporary engineers because Baltzer introduced his 1897 paper on the subject

thus, "To make the paper more interesting and easy to follow, the author has refrained from entering into any abstruse calculations or intricate theory, but touching on the general principles, the opinions and experiences of leading engineers and scientists, and the results authenticated tests".

The theory of Monier arches was presented by Walter Beer in 1898. It is ironic, therefore, to find Baltzer, in giving evidence to the Inquiry, saying that "the line of pressure for the Annandale arches lies within the middle third hence there is no need for the grillage of iron". Indeed, the calculation books of his colleagues in the Public Works Department, particularly H.H. Dare and J.W. Roberts, show that for most Monier arches tensile stresses did not occur, or at worst were very small.

However, when the system was applied to free-standing water tanks, the lattice of iron rods was essential to resist the hoop tension, in fact the concrete merely acts as an impervious shell.

6 REINFORCED CONCRETE

In neither of the two early applications of the Monier System was composite action utilised structurally, but when beams and slabs (originally called plates) were to be constructed then a proper knowledge of the composite behaviour was necessary. The theoretical work was started in Europe by Coignet, Koenen who produced "Das System Monier" in 1886, Tedesco, Rabut, von Bach, Otto Gaf and Ritter just to mention a few (Cowan 1978).

Locally, Professor Warren conducted tests (1902, 1904) on cement mortars and reinforced concrete units to determine strength and elasticity, and a series of papers were published dealing with the theory of reinforced concrete beams (Cutler 1896, Moore 1902, Gummow 1904, Warren 1905).

Simultaneously, there was a flood of text books and manuals such as those by C.F. Marsh 1904, W.N. Twelvetrees 1905, F.D. Warren 1906, Prof. E. Marsh 1909, J.P. Brooks 1911 and B.E. Jones and A. Lakeman 1913. By the beginning of World War I the books on reinforced concrete looked much the same as later books of the 1930's and 1950's, and reinforced concrete had achieved its "modern" image both in terms of design and practice.

7 SCOPE OF APPLICATION 1895-1915

With the success of the Annandale aqueducts, the engineers of the Public Works Department became the leading exponents of the design and construction of reinforced concrete work in New South Wales during the next twenty years. The Annual Reports for that period show the scope of application and the widespread use of the new technology. Other government agencies, such as the Water Board, the Sydney Harbour Trust (later to become the Maritime Services Board) and the Railway Department, embarked on large programmes of reinforced concrete construction which they found to be suitable, economical and durable for the long-term needs of the community.

As the success of these new concrete works became evident and with an increasing influx of information from overseas, engineers and architects in private practice began to include reinforced concrete components such as floor slabs, beams and stairs in their buildings.

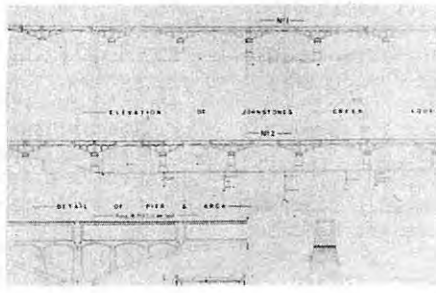
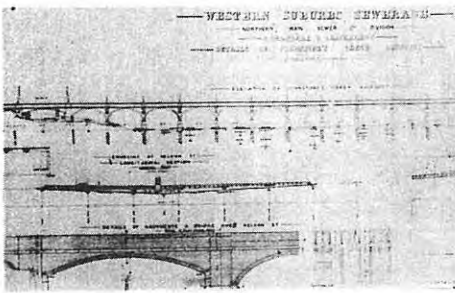


Figure 8 The PWD scheme for the Annandale aqueducts was a series of brick arches (left). The Monier arches (right) were 50% larger in span and their overall cost was 19% cheaper.

Figure 9 F.M. Gummow was the principal pioneer of reinforced concrete in New South Wales. His company built the Annandale aqueducts and fabricated large quantities of concrete pipes. But he was a competent engineer in other fields as the erection of the steel trusses at Singleton in 1904-05 proved.

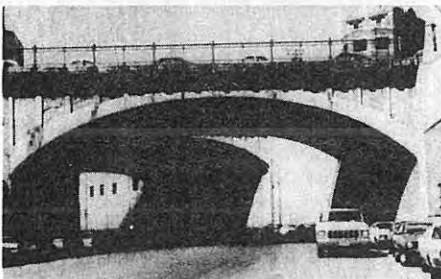
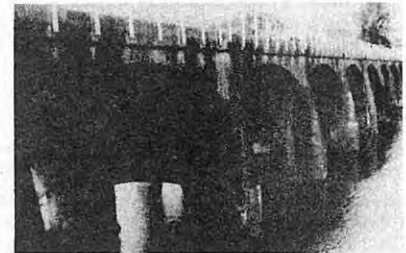
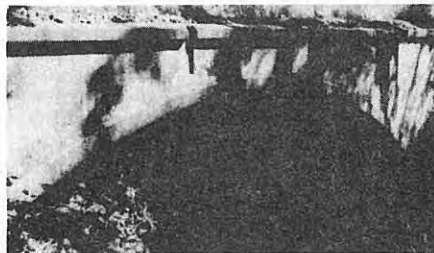
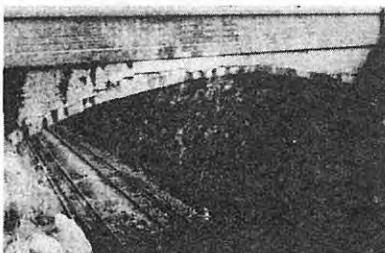
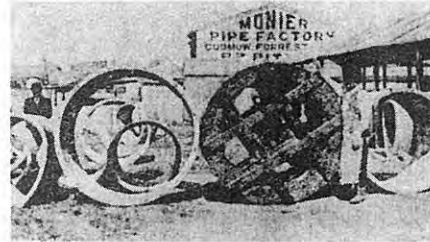


Figure 10 The success of the Annandale aqueducts and of the Monier arch bridges in Germany led to the design and construction of many such road bridges in New South Wales, for example, at Liddell (1898), at Moonbi (1900), at Richmond (1905), and at Walsh Bay, Sydney.

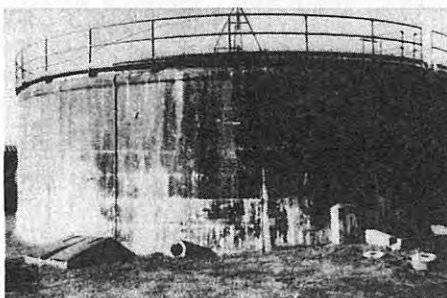


Figure 11 Success and failure in early reinforced concrete construction; the 1899 water tank above Kiama (extant) and the 1909 collapsed Monier tank at Mittagong.

The remainder of the paper is a summary of the scope of application of reinforced concrete between 1895 and 1915. Particularly useful references for identifying those early works are the papers by Bradfield (1900), the discussion to a Warren paper (1907), Mitchell (1922) and the 50th Commemorative issue of *Constructional Review* (1977). The Archives Section of various government agencies were also valuable sources of information. A very fortunate feature of this study was that nearly all of the examples are extant and accessible for inspection.

7.1 Arch bridges

Monier arches became the dominant form of concrete road bridge from 1896 to 1920, particularly over railways. At the time, the Railway Construction Branch was part of the Public Works Department and the design of Monier arch bridges, for both the road and railway works programmes, was performed by such prominent engineers as Harvey Dare, J.W. Roberts and J.J.C. Bradfield.

A semi-circular concrete arch was built over Black Bobs Creek in 1896 but its proportions are more like a Roman arch than the flatter Monier construction. The first of the new style was built over the railway cutting at Hill Top in 1897 followed by the much larger arch at Liddell in 1898 to carry the Great North Road (New England Highway) over the double track Main North railway, figure 10. A series of railway overbridges followed, over the Main North line between Hornsby and Cowan, the Main South line from Bargo to Cootamundra, and along the Main West from Glenbrook to Lithgow.

In 1900 the Roads and Bridges Branch had their first Monier arch constructed over Moonbi Creek, north of Tamworth, figure 10 (Main Roads 1978) followed by the viaduct of thirteen arches across the Hawkesbury River at Richmond in 1905.

The Sydney Harbour Trust also showed a passing interest in Monier arches and built three over the rock cutting that is Hickson Road passing from Darling Harbour to Walsh Bay, figure 10. These 24 m (80 feet) arches support Munn, Argyle and Windmill Streets, and at the time of their construction 1910-1914 were noted by the *Daily Telegraph* (1911) as the "largest reinforced concrete bridges in New South Wales."

7.2 Reservoirs

The Monier System had been successfully used in Germany for water tanks and pressure vessels, consequently the Water Board and the Water Supply Branch of the Public Works Department began building water tanks very soon after the Inquiry had officially endorsed Monier construction.

The first reinforced concrete water tank above ground was built on a hill above Kiama in 1899, figure 11, and soon after, a similar tank was constructed in the south-west corner of the Randwick Racecourse grounds. Beginning with the Mt. Pritchard (Liverpool) reservoir in 1901, the Water Board built a series of on-ground and elevated service reservoirs Howard Street Randwick 1910, Drummoynes 1910 and Bellevue Hill 1912 just to mention a few. The Public Works Department built the water supply tank for Corowa in 1906, and two Monier reservoirs were built for Pelow Main and Neath coal mines in 1908 and 1909 (Henson 1910).

But the introduction of the new technology was not without blemish. On January 22, 1909 the newly-built service reservoir at Mittagong collapsed, figure 11,

and spilled 200,000 gallons down the hill (Town and Country Journal, January 27, 1909). E.M. De Burgh inspected the ruins and said "there was no theory as to the bursting, as a number of exactly similar tanks in other parts of the country are all giving entire satisfaction". Errors in construction and some inexperience by the contractors seem to have been the cause, however it did not halt the construction of the elevated service reservoirs that occupy many of the high spots in and around Sydney.

7.3 Monier pipes

G.W. Mitchell (1922), who was Director-General, Department of Public Works in 1914, at the time the government acquired the Monier Pipe Works, claimed that in 1897 the making of Monier pipes was on a small scale because the pipes, made by the European system, had insufficient breaking strength. The design was carefully investigated and numerous tests were made to assess the best amount of reinforcement and its location. The new product "placed Australia ahead of other countries in this section of the use of reinforced concrete". From that time, the use of Monier pipes for sewerage and stormwater drainage became general, and the output of standard units increased rapidly.

Despite the thousands of pipe lengths used, the author has yet to see an example exposed in the ground, but an application of Monier pipes that has been easy to see is their use for bridge piers.

Around 1900, timber piles were still the dominant element of bridge piers, but in spite of the great density and durability of the Australian hardwoods, they were not immune to insect attack and wet rot. Both tended to be most troublesome at the ground line and in the length wetted by the tidal range. Sheathings of copper and Muntz metal had not proved satisfactory but the strength and durability of a reinforced concrete cover offered considerable improvements.

E.M. De Burgh (1900) recognised "that pipes constructed on the Monier principle, in which steel nettings and wires are introduced into the body of the cement forming the pipe, would be very suitable for pile coverings". The first application was in the construction of the road bridge over Cockle Creek, south of Newcastle, in 1901 (DMR archived plan No. 9001714). But Monier pipes, filled with concrete, were also used at many other sites to form the main pier unit, figure 12, instead of timber piles.

7.4 Sea walls

A feature of the introduction of any new technology is that some of its uses are determined by social rather than technical factors. The first use of reinforced concrete by the Sydney Harbour Trust was just such a case. At the turn of the century the shipping and commercial areas of Sydney Harbour were unpleasant waterways due to the presence of dead carcasses, offal and other foul flotsam. The residential strip, between the wharves of Darling Harbour and the City, was a squalid slum and ships' crews did little to control the influx of rats. Consequently, Sydney had a rat plague, figure 13.

The Sydney Harbour Trust was established to bring some order to and planning for the Harbour and to clean up the mess. One of the problems was the ease with which rats could swim at will and climb up wooden sea walls or run along drainage/sewer pipes into the slum areas. The success of the eradication programme and of the remodelling of the Kent Street-Rocks areas is a very interesting social story in its

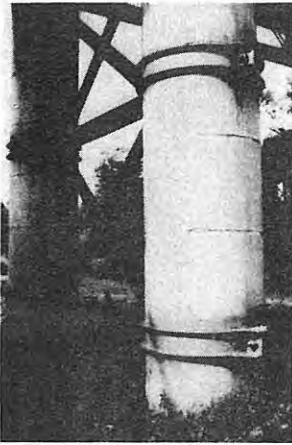


Figure 12 Monier pipes with in-fill concrete were used as piers for road bridges at many locations in New South Wales.

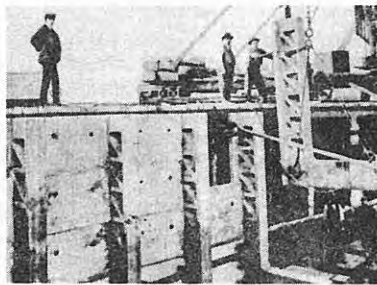


Figure 13 One of the methods for solving Sydney's rat plague was to build smooth-faced concrete sea walls using precast reinforced concrete units.

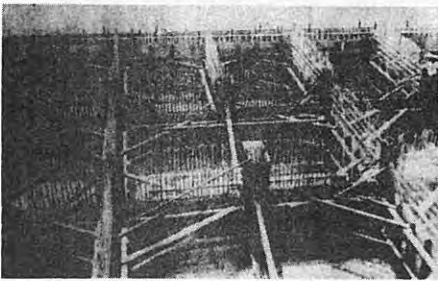
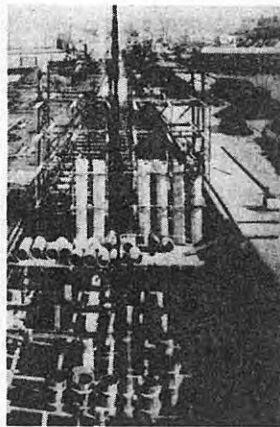


Figure 14 Examples of the scope of application of reinforced concrete for harbour works early this century; a navigation beacon, a pontoon, and the Woolloomooloo wharf.

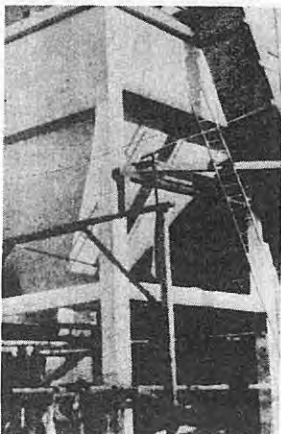
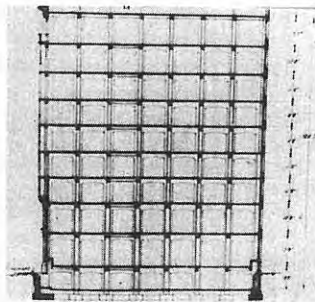


Figure 16 Three examples of reinforced concrete building construction before World War I; the Coogee Beach pavilion and a coal hopper in Parramatta, and the line drawing for No. 49 Wentworth Avenue - the building has reinforced concrete floors.



Figure 15 The canals of Sydney's water supply scheme were liner with reinforced concrete during the period from 1905 to 1913.

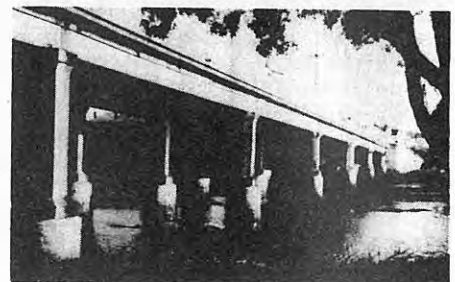
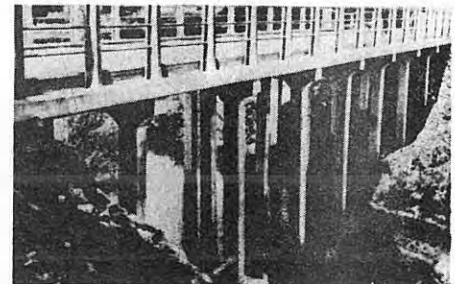


Figure 17 The 1914 slab bridge over American Creek, Fig Tree (replaced); the 1916 beam bridge, Wickham, Newcastle.

own right, but its involvement with the early years of reinforced concrete stems from the use of precast reinforced concrete to form a smooth face on the tidal side thereby effectively restricting the free-roaming habits of the rats.

During the recent reconstruction of the wharves of Darling Harbour north of Pyrmont Bridge, the early precast concrete sea wall was either demolished or abandoned, but south of Pyrmont Bridge and in Walsh Bay, sections remain and are clearly visible at low tides.

7.5 Other harbour works

The Harbour Trust engineers were quick to see other uses for the new material; just three are mentioned here and illustrated in figure 14. Navigation beacons were constructed of reinforced concrete at many locations in the Harbour and on its foreshores.

Wharf decks formed by reinforced concrete slabs were superior to wooden planks, consequently the large programme of wharf construction prior to World War I included such decks as standard practice. When the Trust decided in 1910 to build a new pontoon for Nos. 6 and 7 Circular Quay, timber and iron were rejected in favour of reinforced concrete. The unit was 33m long x 20m wide x 2.4m deep, weighed 600 t and had 44 watertight compartments. The Evening News of November 13, 1913 claimed that it was the largest of its type in Australia.

7.6 Canal linings

The Water Board extended the use of reinforced concrete from service reservoirs to lining the water supply canals, figure 15, during the years 1905 to 1913, and the lined sections are easy to see at the Prospect Reservoir outlet and where roads cross the canals in many places.

7.7 Buildings

From around 1910, architects and structural consulting engineers began to incorporate reinforced concrete floor slabs, beams, stairs and walls into their building designs. The columns were either cast iron or fabricated steel and the main walls were solid brick; the all-concrete building did not appear until the 1920's. Four existing buildings from the period are the Australian Gas Light building in Parker Street, Ushers/Carlton Hotel in Castlereagh Street, Commonwealth Bank on the corner of Martin Place and Pitt Street, and William Adams' old workshop in Alexandria. Figure 16 shows three early examples of reinforced concrete building construction.

7.8 Slab and beam bridges

By 1914 the theory and practice of reinforced concrete in bending was well understood overseas and the bridge design engineers of the Public Works Department were ready to extend the application of reinforced concrete from Monier arches to beam and slab construction.

The first of these was a slab bridge, figure 17, over American Creek near Fig Tree, Woolongong, completed in 1914 but recently replaced. In the same year a small slab bridge was built over Tooles Creek south of Wagga Wagga, which has been widened using beam and slab construction.

There followed in quick succession a series of beam/slab bridges, over Mullet Creek near Dapto in 1916, over Throsby Creek, Newcastle, figure 18, also

dating from 1916 (both extant) and over Shark Creek, Maclean. The latter was replaced in 1937 by the present concrete bowstring arch.

With the success of these bridges and the end of World War I, a whole new era of road bridge construction began, so much so that for the next fifty years reinforced concrete was the dominant form of construction.

7.9 Other works

The research into the early use of reinforced concrete is continuing and it is most likely that other applications will be revealed. For example, the author believes that some sections of reinforced concrete road pavement were built in New South Wales around the time of World War I, but has yet to find the evidence.

A reinforced concrete chimney was built at the Ryde Pumping Station in 1916 but demolished in 1982; and some hoppers and silos were built for private companies.

The examples quoted in this paper are far from exhaustive.

8 CONCLUSION

The development and use of any engineering technology is part of the total history of a community. The contemporary social attitudes, politics, economic factors and personalities all influence the success, or otherwise, of that technology. So it was with the introduction of reinforced concrete into New South Wales. Although technical papers from 1898 to 1915 illustrated the developments in theory, design and application, it was the result of a political row and the subsequent Royal Commission that revealed the origins of reinforced concrete in New South Wales.

The experienced historian is well aware of this technical-social interplay and so too must be the engineering historian, because, without identifying the impact of those other factors, the technical story is incomplete.

Reinforced concrete has become, after ninety-five years, a common part of our built environment, and we are fortunate that its durability has allowed a great many of the original applications to be extant. Most of these are actually still in use, and nearly all are readily accessible for inspection. Collectively, they form a significant body of hard evidence of our engineering heritage.

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For photo and biographical details, see page 81